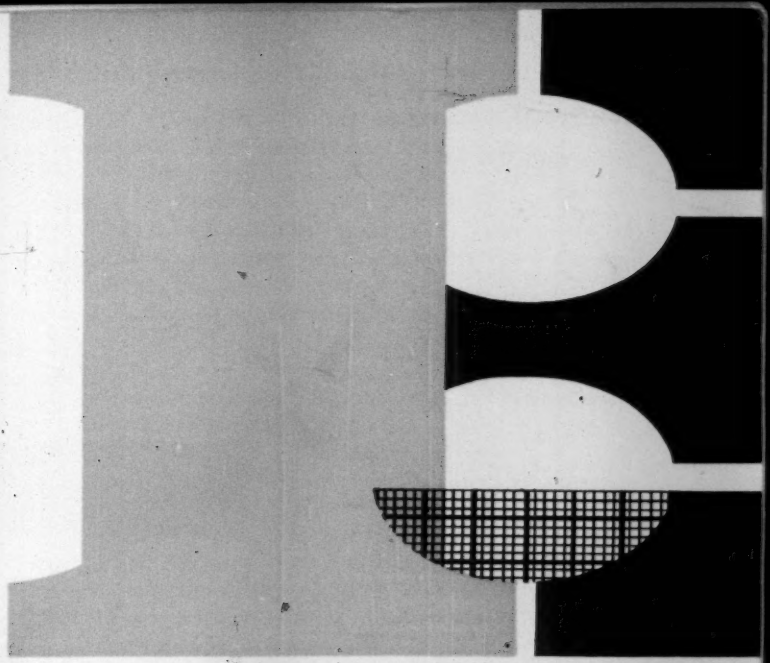

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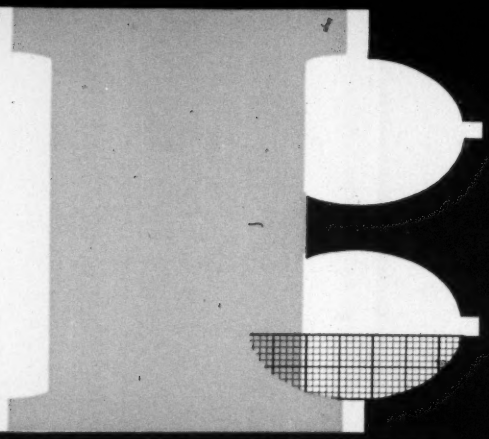

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Optimal Locations for Multiple Machines[1]

by JAMES M. MOORE[2]

Department of Industrial Engineering, Stanford University

THE LOCATION of several new machines in an existing plant layout is limited to a number of possibilities, none of which is necessarily ideal. The determination of the best of the available layouts is a problem that can be solved with a simple mathematical procedure. This presentation provides an analytical tool for optimally locating more than one new machine in a fixed existing layout. The technique used here has been developed in the operations research field and used for assigning job applicants to jobs in such a manner that an overall measure of effectiveness is optimized. In the operations research literature this problem is called "The Assignment Problem."

The material here is an extension of the work in (2) and (8) where a procedure is suggested for locating a single new machine in an optimal manner in an existing layout. The single new machine limitation can be dropped by introducing the assignment approach thus making the technique more generally applicable.

Plant layout problems can be handled using either discrete or continuous locations. Most of the work to date (3) (5) (10) (12) has assumed that locations for the new equipment are discrete. If a grid were to be superimposed over an existing plant layout and new machines, which are themselves considered as point locations, could be located only at the intersection of the grid lines in the candidate areas, we have an example of discrete locations. A continuous location problem would exist if the new machines could be located anywhere within the candidate area, that is, between the grid lines as well as on them.

When a new plant is to be built where the only layout restriction is the building configuration, continuous locations make more sense than discrete candidate areas. This is the most general layout problem for which there has been no solution proposed as yet. Wimmert (12) and Conway (5) examine this problem but limit themselves to discrete candidate locations. They propose that the new machines establish a manufacturing process which is completely independent of any of the existing equipment, that is, no materials will move from any of the new machines to any of the existing machines. This situation is certainly possible, but rather seldom found in practical cases. If the new process is actually independent of existing facilities, it should be located in its own area rather than "fitted into" an existing layout. Therefore when independence does exist, continuous rather than discrete locations should be used.

The assignment model proposed here opposes the Wimmert-Conway view and assumes that all new machines will have materials handling contact with the existing machines. Fitting the new machines into the existing layout is justified in this case because they are to become a part of the existing manufacturing process. Discrete candidate areas for locating the new machines are still used because the locations of the existing machines are not available.

OPTIMAL LOCATION OF *N* NEW MACHINES

In order to solve the layout problem utilizing the assignment problem, it is necessary to develop an effectiveness matrix. Let us consider the following simple example for illustrative purposes.

Two new lathes are to be placed in an existing layout. The new lathes, a South Bend (SB) and a Browne and Sharpe ($B+S$), can be located in either of the candidate areas A or B. The question is where each should go. Figure 1 shows the location of the two candidate areas. It also shows three machines already in the layout with which the new machines will have a materials handling relationship. Figure 2 gives the estimated production volume in skids per week that will pass between each of the new machines, the South Bend and the Browne and Sharpe, and the existing machines which are merely numbered 1, 2 and 3.

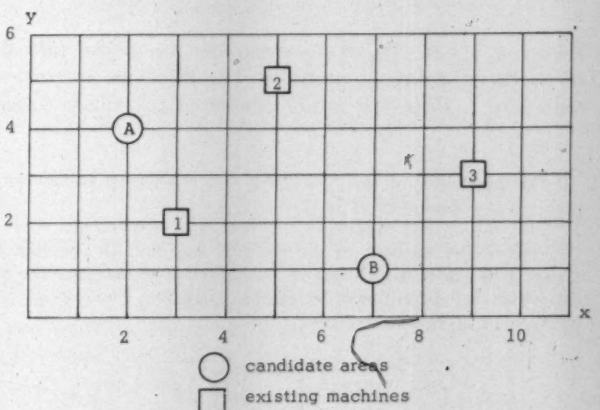

FIGURE 1

[1] This article summarizes a portion of the author's thesis entitled "Mathematical Models for Optimizing Plant Layouts" prepared for the Department of Industrial Engineering at Stanford University. The author would like to express his appreciation for the helpful comments and suggestions provided by Professor W. Grant Ireson and Dr. Daniel Teichroew, both of Stanford University.

[2] Present address, Department of Industrial Engineering, Northeastern University.

	To Existing Machines		
	1	2	3
South Bend	10	2	5
From Browne and Sharpe	0	7	5

FIGURE 2

Assuming that in this problem we are willing to settle for a measure of effectiveness of skid-feet per week,[3] the information given in Figures 1 and 2 is sufficient to develop an effectiveness matrix.

The first step is to establish the distance matrix from the information given in Figure 1. If rectangular movement only is used in this problem, the distance matrix is developed as is shown in Figure 3.

		To Existing Machines		
		1	2	3
From Candidate Areas	A	3	4	8
	B	5	6	4

Feet/10^2

FIGURE 3

Utilizing Figures 2 and 3, an effectiveness matrix can be developed using matrix multiplication. In matrix form, this multiplication[4] looks like:

$$\begin{pmatrix} 3 & 4 & 8 \\ 5 & 6 & 4 \end{pmatrix} \begin{pmatrix} 10 & 0 \\ 2 & 7 \\ 5 & 5 \end{pmatrix} = \begin{pmatrix} 78 & 68 \\ 82 & 62 \end{pmatrix}. \qquad \text{Eq. 1.}$$

In the terms of our layout problem this matrix multiplication operation is saying, for example, if the South Bend is placed in candidate area A, the measure of effectiveness will be

$$3(10) + 4(2) + 8(5) = 78 \text{ skid-feet per week} \times 10^{-2}.$$

Figure 4 places the effectiveness matrix in the format of the 2 by 2 layout problem. The numbers are taken from Eq. 1. With the establishment of the effectiveness matrix, the layout problem has been formulated in the form of the assignment problem.

[3] The worthiness of this "yardstick" for evaluating layout proposals is discussed in detail in (7).

[4] The reader will recognize the matrix multiplication operation where the element in the ith row and the jth column of matrix C is equal to the sum of the products of the elements of the ith row of A multiplied by the corresponding elements of the jth column of B. For example,

$$AB = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \\ b_{31} & b_{32} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} = C$$

where

$$c_{ij} = a_{i1}b_{1j} + a_{i2}b_{2j} + a_{i3}b_{3j}.$$

DEFINITION OF THE ASSIGNMENT PROBLEM

Churchman (4) describes the assignment problem as follows:

> Given n facilities and n jobs, and given the effectiveness of each facility for each job (the table which contains the n^2 values of effectiveness is called an $n \times n$, or n^2, matrix), the problem is to assign each facility to one and only one job in such a manner that the given measure of effectiveness is optimized.

Perhaps this is best illustrated by the personnel assignment problem. Suppose that there are n applicants for n jobs. The applicants can be denoted by the index $i = 1, 2, \ldots, n$, and the jobs by the index $j = 1, 2, \ldots, n$. The applicants are tested as to their expected job performance for each of the jobs. From these tests the number r_{ij}, which is the measure of effectiveness of the ith applicant in the jth job, is developed. The problem is to assign the applicants to jobs such that the overall effectiveness is optimized. Of course, this does not guarantee that the applicant with a high score for a particular job will be assigned to it because only overall effectiveness is considered.

		New Machines	
		SB	$B+S$
Candidate Areas	A	78	68
	B	82	62

FIGURE 4

Munkres (9) states the problem mathematically as follows:

> Let r_{ij} be the performance rating of man M_i for job J_j. A set of elements of a matrix are said to be independent if no two of them lie in the same line (the word "line" applies both to the rows and to the columns of a matrix). One wishes to choose a set of n independent elements of the matrix (r_{ij}) so that the sum of these elements is a maximum. Let $r = \max_{ij} r_{ij}$, and let $x_{ij} = r - r_{ij}$. An equivalent problem is to choose a set of n independent elements of the matrix $A = (x_{ij})$ such that the sum of these elements is minimum.

It is the solution to this minimization problem that is useful in plant layout. The most widely proposed measure of effectiveness for evaluating layout arrangements is the product of the traffic times distance where traffic can be volume, weight, priority, etc. and distance can include time, cost, difficulty of handling as well as physical distance. This measure of effectiveness is to be minimized.

SOLUTION OF THE ASSIGNMENT PROBLEM BY THE HUNGARIAN METHOD

The Hungarian Method, first proposed by Kuhn (6), is the most efficient routine for solving the assignment problem to date. It is based upon a theorem proved by

		New Machines SB	$B+S$
Candidate Areas	A	0	6
	B	4	0

FIGURE 5

the Hungarian mathematician D. König in 1916, hence its name. Beckwith and Vaswani (1) described the algorithm in detail in an earlier issue of the *Journal of Industrial Engineering*. Sasieni (11) provides an excellent introduction to the Hungarian Method.

It suffices here to indicate in summary form the steps involved in using the Hungarian Method to solve the assignment problem.

1. Subtract the minimum of each row from all elements of the row in the effectiveness matrix. Then in the resulting matrix, subtract the minimum element of each column from all the elements of the column, obtaining the first reduced matrix.
2. Determine the optimal assignment. If the optimal assignment is a feasible solution, the procedure terminates here. If not, step 3 must be executed.
3. Cover all zeros with the minimum number of straight lines. Find the smallest element *not* covered by a line. Subtract this minimum element from all elements not covered by lines; and then add it to all elements lying at the intersection of two lines, which reveals the second reduced matrix.
4. Repeat steps 2 and 3 until a complete feasible solution is obtained.

Returning to the example problem discussed earlier, the first reduced matrix using the Hungarian Method is shown in Figure 5. As it turns out in the example, a complete solution is found after performing step 1. The optimal solution then for this problem is to put the South Bend in candidate area A and the Browne and Sharpe in area B.

As the candidate areas increase in number, the computational effort involved in determining the effectiveness matrix increases; however, it is a computation that lends itself nicely to computer calculation.

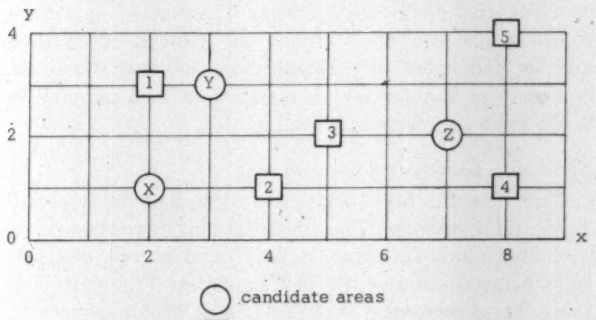

FIGURE 6

Example: Robinson Trailer Company

The layout problem at Robinson Trailer Company can be used to illustrate a larger scale and more realistic problem. Robinson wants to add three new pieces of equipment, let us call them A, B and C, to their existing layout. Their product is of sufficient size so that a lift truck can carry no more than one at a time. Truck movement is limited to rectangular directions. Figure 6 shows the location of the candidate areas where these new machines may be placed as X, Y and Z. It also shows the existing machines, numbered 1 to 5, and their locations.

Figure 7 gives the expected production volume between the new and existing machines. Notice that it is not

		Existing Machines 1	2	3	4	5
New Machines	A	25	8	4	0	30
	B	0	7	10	12	8
	C	8	5	60	0	16

FIGURE 7

necessary for each of the new machines to have a materials handling relationship with all of the five existing machines. The zero entries in Figure 7 indicate that no materials pass between the associated equipment. For example, no material will pass between new machine B and existing machine 1.

Taking rectangular distances from Figure 6, the distance matrix is developed as shown in Figure 8. Matrix multiplication of the volume matrix and the distance matrix develops the effectiveness matrix as follows:

$$\begin{pmatrix} 25 & 8 & 4 & 0 & 30 \\ 0 & 7 & 10 & 12 & 8 \\ 8 & 5 & 60 & 0 & 16 \end{pmatrix} \times \begin{pmatrix} 2 & 1 & 6 \\ 2 & 3 & 4 \\ 4 & 3 & 2 \\ 6 & 7 & 2 \\ 9 & 6 & 3 \end{pmatrix}$$

$$= \begin{pmatrix} 352 & 241 & 280 \\ 208 & 183 & 96 \\ 410 & 209 & 236 \end{pmatrix} \quad \text{Eq. 2.}$$

Figure 9 puts the effectiveness matrix into the context of the problem and shows the results of the application of step 1 of the Hungarian Method. The effectiveness matrix for the Robinson Trailer problem is shown on the left, while the middle and right matrices indicate the results from step 1 of the Hungarian Method.[5]

[5] The notations used in the matrix operations, that is, the $\square$ and $\times$, are the same as used in (11).

		Candidate Areas		
		X	Y	Z
Existing Machines	1	2	1	6
	2	2	3	4
	3	4	3	2
	4	6	7	2
	5	9	6	3

FIGURE 8

Therefore a feasible and optimal layout solution is to

Assign A to Candidate X,
Assign B to Candidate Z,
Assign C to Candidate Y.

It is easy to see how the Robinson Trailer problem could be expanded to include n new machines to be located in n candidate areas.

chines to be located. These identical machines will require one skilled machinist between them, therefore must be located together. How can locating more than one new machine in a given area be handled when each machine has a different production volume pattern? One method of handling this situation would be to consider the two identical machines as a production center and total their production volume requirements. They could then be handled in the assignment problem as if they were only one machine. Of course, if this is done, precautions must be taken to assure that assumption 2 is not violated.

Assumption 2 demands that each new piece of equipment can be located feasibly in each candidate area. For example, suppose that all candidate areas are quite large except one, which is a six foot square. If the new machines are four upright drill presses and one six-spindle automatic screw machine, which is twelve feet in length, it can be seen that the drill presses will fit into any candidate area; however, the automatic screw machine is much too large for the small candidate area. Fortunately

	Candidate Areas		
	X	Y	Z
A	352	241	280
New Machines B	208	183	96
C	410	209	236

Candidate Areas		
X	Y	Z
111	0	39
112	87	0
201	0	27

Candidate Areas		
X	Y	Z
[0]	0	39
1	87	[0]
90	[0]	27

FIGURE 9

Although the examples have been rectangular movement situations, it can be seen that it would be just as easy to use straight-line movement data in the distance matrix as rectangular movement data. Space will not be consumed with an illustrative example combining the assignment problem and straight-line movement since the transition seems obvious. Mathematical methods for obtaining the straight-line movement distances are somewhat more involved than the rectangular movement situation, but in our layout problem, obtaining these data by graphical methods is quite easy.

ASSUMPTIONS

Two assumptions have been made, but not stated, in utilizing the assignment problem which may be stumbling blocks in practical situations. These assumptions are:

1. Only one machine can be located in each candidate area.
2. Any new machine is acceptable in any candidate area.

The first assumption leaves some doubt on how one might handle the following question. Suppose there are two identical pieces of equipment among the new machines to be located. These identical machines will require one skilled machinist between them, therefore must be located together. How can locating more than one new machine in a given area be handled when each machine has a different production volume pattern? One method of handling this situation would be to consider the two identical machines as a production center and total their production volume requirements. They could then be handled in the assignment problem as if they were only one machine. Of course, if this is done, precautions must be taken to assure that assumption 2 is not violated.

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NONSQUARE ASSIGNMENT PROBLEM

In order to use the Hungarian Method the effectiveness matrix must be a square matrix, that is, it must be n by n. However, layout problems are frequently encountered in which the effectiveness matrix is presented in a form which is not square. Applying the Hungarian Method directly can result in a suboptimum solution. However, it is easy to convert such a matrix into a square matrix as shown in the following example.

Example: Bucknall Tool and Die

Three new machines are to be installed at the Bucknall Tool and Die shop. The present plant layout suggests that four candidate areas, A, B, C, and D, are available for the installation of the new machines. Figure 10 contains the effectiveness matrix for this problem.

Figure 11 shows the results of applying steps 1 and 2 of the Hungarian Method directly to this three by four matrix. The result is a suboptimum solution to the problem.

	Candidate Areas			
	A	*B*	*C*	*D*
1	56	67	80	66
Machine 2	60	77	82	60
3	68	75	28	73

FIGURE 10

Ignoring the square matrix requirement of the Hungarian Method, one might be led to think that the solution proposed in Figure 11 is an optimum solution. It appears that the machines should be arranged as follows:

Machine		Candidate Area
1	assigned to	*B*
2	assigned to	*D*
3	assigned to	*C*

However, the total measure of effectiveness indicated by this solution is

$$M = 67 + 60 + 28 = 155,$$

which we will see is not the minimum in this problem.

	Candidate Areas			
	A	*B*	*C*	*D*
1	~~0~~	[0]	24	10
Machine 2	~~0~~	6	22	[0]
3	40	36	[0]	45

FIGURE 11

It is a simple matter to convert the effectiveness matrix to a square matrix by introducing a dummy machine. Because there will be no flow of product from this machine, the entries in the dummy row will all be zeros. Figure 12 shows the effectiveness matrix revised to include the dummy machine which transforms the matrix to an n by n matrix.

	Candidate Areas			
	A	*B*	*C*	*D*
1	56	67	80	66
Machine 2	60	77	82	60
3	68	75	28	73
Dummy	0	0	0	0

FIGURE 12

The application of the Hungarian Method to the revised effectiveness matrix results in a different assignment. Figure 13 contains the optimal assignment as indicated by the use of steps 1 and 2. The optimum assignment is shown as *A*-1, *C*-3 and *D*-2, while candidate area *B* will go unused.

	Candidate Areas			
	A	*B*	*C*	*D*
1	[0]	11	24	10
Machine 2	~~0~~	17	22	[0]
3	40	47	[0]	45
Dummy	~~0~~	[0]	~~0~~	~~0~~

FIGURE 13

The measure of effectiveness now is less than the one corresponding to Figure 11. It is

$$M = 56 + 28 + 60 = 144.$$

In general the assignment problem which has an effectiveness matrix $(n \times m)$ where $m < n$ can be converted to an $(n \times n)$ matrix by the addition of $(n - m)$ dummy columns. In a similar manner a matrix may be "squared up" by the addition of rows if the effectiveness matrix is $(n \times m)$ where $n < m$.

PROHIBITED ASSIGNMENTS

In plant layout problems there may be any number of reasons why machine-candidate combinations are prohibited. Some of these reasons might be listed as follows:

1. New machine is too large for the candidate area.
2. Proper labor force skills demanded by the new machine are not available within the area.
3. Supervisory personnel needed by the machine are unavailable.
4. Vertical clearances in the candidate area are insufficient.
5. Proper factory services are unavailable, that is, compressed air or chip removal facilities.
6. Appropriate materials handling equipment unavailable.

In the earlier examples all entries in the effectiveness matrix were finite elements, that is, $c_{ij} < \infty$. However, this need not be the case. For example, if any of the restrictions just mentioned prohibit any particular combination, an arbitrarily high (infinite) cost can be associated with the corresponding a_{ij}, that is, $a_{ij} = \infty$. If this is done, this combination will be automatically excluded from the optimum solution.

Suppose in the Bucknall Tool and Die problem that the new machine number 2 was much too large for candidate area *D*. Matrix I in Figure 14 indicates how the effectiveness matrix shown in Figure 12 can be altered so that the optimum solution will exclude the undesirable combination 2-*D*.

Matrix II of Figure 14 reflects the application of steps 1 and 2 of the Hungarian Method. However, this results

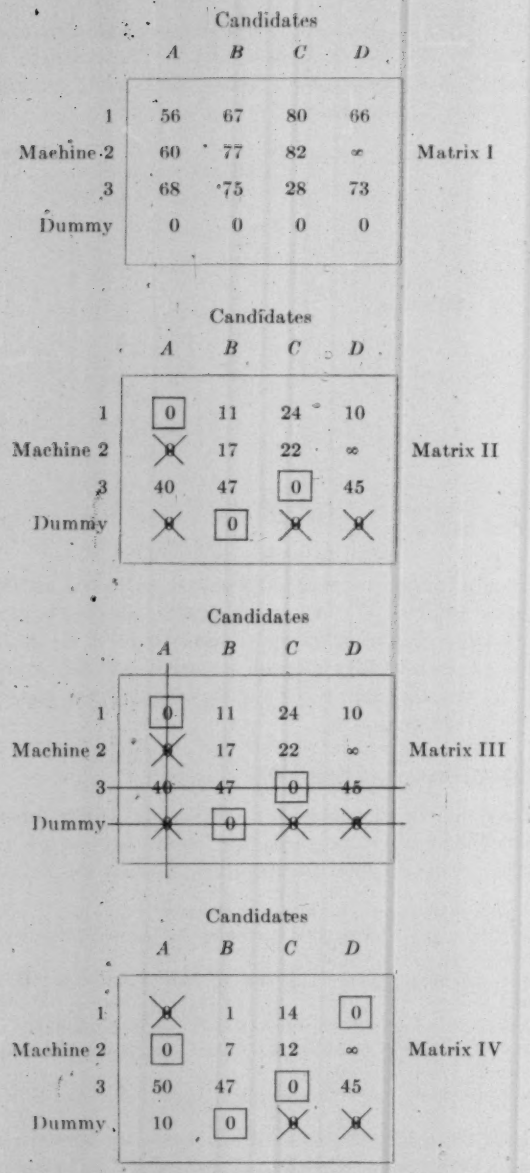

FIGURE 14

in an infeasible solution, because machine 2 is not assigned an area. It is therefore necessary to invoke step 3 of the Hungarian Method. Matrix III shows how this is developed.

Matrix IV of Figure 14 reveals an optimum-feasible solution to the problem with combination 2-*D* excluded as a possibility. The measure of effectiveness for this solution is

$$M = 60 + 0 + 28 + 66 = 154.$$

It should be noted that adding the constraint eliminating combination 2-*D* has caused the measure of effectiveness to increase by ten units over the original optimum solution. This seems intuitively logical; however, it can be seen by examining Figure 13 that if the prohibited combination had been 1-*C*, for example, the original optimum solution would not have been altered. This is to say that in a problem with prohibited assignments the measure of effectiveness in the optimum solution may increase, but not necessarily.

EVALUATION OF ASSIGNMENT MODEL

The assignment model appears to have real value in analyzing plant layout problems where m machines are to be located in n candidate areas. The effectiveness matrix can be easily generated by matrix multiplication and the Hungarian Method applied to it to obtain an optimum overall assignment.

Nevertheless, there are limitations to this model. It will assign a small machine to a large candidate area resulting in a large amount of wasted space in the area. It may be more reasonable to place two machines in this large candidate area. However, this development cannot come about via the assignment model. Perhaps in such a situation large candidate areas should be divided up into smaller candidates.

Another limitation to this model is the independence between the new machines. The model demands that there be no materials handling contact between the new machines. It is easy to conceive of a situation where parts would be moved from new machine 2, for example, to new machine 3. The model as described here is not capable of coping with this practical situation. However, it appears that it may be possible to remove this restriction by setting the problem up in the format of the general linear programming problem. In this form it appears likely that one may be able to attack the general plant layout problem discussed earlier using continuous rather than discrete locations. Further research is in progress to establish these points.

This model has been limited to deterministic traffic data. If traffic data can be taken with a high degree of confidence, then this procedure should work well. However in practical situations it is more likely that traffic data will be stochastic and subject to random variations. Further study is needed to determine the sensitivity of the layout solution to traffic variations. Even with these limitations the assignment model promises to be a useful tool in analyzing layout problems.

REFERENCES

(1) BECKWITH, RICHARD E., AND VASWANI, RAM, "The Assignment Problem—A Special Case of Linear Programming," *Journal of Industrial Engineering*, Vol. VIII, No. 3, May-June, 1957, pp. 167-172.

(2) BINDSCHEDLER, ANDRE E., AND MOORE, JAMES M., "Optimal Location of New Machines in Existing Plant Layouts," *Journal of Industrial Engineering*, Vol. XII, No. 1, January-February, 1961, pp. 41-48.

(3) BUFFA, ELWOOD S., "Sequence Analysis for Functional Lay-

outs," *Journal of Industrial Engineering*, Vol. VI, No. 2, March-April, 1955, pp. 12-25.
(4) CHURCHMAN, C. WEST, *et al.*, *Introduction to Operations Research*, John Wiley and Sons, New York, 1957, p. 343.
(5) CONWAY, RICHARD W., AND MAXWELL, W. L., "A Note on the Assignment of Facility Location," *Journal of Industrial Engineering*, Vol. XII, No. 1, January-February, 1961, pp. 34-36.
(6) KUHN, H. W., "The Hungarian Method for the Assignment Problem," *Naval Research Logistics Quarterly*, Vol. 2, Nos. 1 and 2, March-June, 1955, pp. 83-97.
(7) MOORE, JAMES M., "Mathematical Models for Optimizing Plant Layouts" (Unpublished Doctoral Dissertation, Department of Industrial Engineering, Stanford University, 1961).
(8) MOORE, JAMES M., *Plant Layout and Design*, The Macmillan Company, New York, 1961.
(9) MUNKRES, JAMES, "Algorithms for the Assignment and Transportation Problems," *Journal of the Society for Industrial and Applied Mathematics*, Vol. 5, No. 1, March, 1957, p. 32.
(10) NOY, PETER C., "Make the Right Plant Layout—Mathematically," *American Machinist*, Vol. 101, No. 6, March, 1957, p. 121.
(11) SASIENI, MAURICE, ET AL., *Operations Research—Methods and Problems*, John Wiley and Sons, New York, 1959, pp. 185-194.
(12) WIMMERT, R. J., "A Mathematical Method of Equipment Location," *Journal of Industrial Engineering*, Vol. IX, No. 6, November-December, 1958, p. 498.

Work Simplification Applied to Occupational Rehabilitation

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A CONSTANT campaign is being waged to have industry employ the physically handicapped. Foremost leaders in this campaign are the federal, state, and local governments. The United State Department of Health, Education, and Welfare's Office of Vocational Rehabilitation, and similar agencies of the various states offer medical service, counseling and guidance, vocational training and job finding to the physically handicapped in order to help these workers reestablish themselves as a productive part of the community (13) (15). In addition, the federal government has been promoting an educational program for the purpose of teaching the nation to accept and use the abilities of the physically handicapped. This program has included posters, pamphlets, postage cancellation, and a commemorative postage stamp which was issued in 1960.

Both union and management are promoting educational programs urging the employment of the physically handicapped. The American Federation of Labor and Congress of Industrial Organizations, the National Association of Manufacturers, and individual unions and companies have publicly advanced and promoted the hiring of these workers (9) (11). Many organizations and societies are also active in the field of occupational rehabilitation. One, the National Rehabilitation Association, was organized for state and federal rehabilitation counselors, physicians, social workers, rehabilitation center personnel, and allied personnel and is dedicated to the welfare of handicapped persons (7). Other organizations interested in occupational rehabilitation include the President's Committee on Employment of the Physically Handicapped, The National Society for Crippled Children, the American Heart Association, and the Federal Association for Epilepsy (10) (12) (14). Among prominent Americans who have given their time and effort to occupational rehabilitation are such names as Arde Bulova and Conrad Hilton (1) (4).

The purpose of occupational rehabilitation is not to be charitable, but rather to make every rehabilitated worker a productive member of society. A rehabilitated worker becomes so integrated when he is employed on a job in which his disability or handicap does not interfere with his work. As long as a man has all necessary abilities and requirements of a particular job, he is able to be productive. Many determined Americans have overcome physical disabilities to live useful and productive lives (16) (18). Alexander Graham Bell and Franklin Delano Roosevelt are well-known examples. Many more individuals could be rehabilitated if only additional industries and businesses would take an active part in hiring rehabilitated workers. A man *must* be hired for what he can do despite his disability, not for what he cannot do because of his disability.

WHAT OF THE ENGINEER?

With all this attention placed on occupational rehabilitation it is disappointing to discover that engineers have done little as a group in assisting and promoting this pro-

gram. Individuals have done much, but what is needed is the cooperation and help of all engineers.

In 1955, the American Institute of Industrial Engineers issued the following policy statement defining the position of Industrial Engineering (8):

> Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials, and equipment. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such a system.

Thus Industrial Engineering, of all the engineering fields, is best qualified to promote occupational rehabilitation. Its qualifications are based on three important principles: First, it is the only branch of engineering interested in the entire man-machine system or process. The worker is an important part of the system, and his effectiveness can determine whether or not the system will be successful. Second, Industrial Engineering is also very interested in the design and improvement of equipment and products. Third, Industrial Engineering uses scientific techniques in problem solution.

This unique combination of the foregoing three factors makes Industrial Engineering ideally suited for work in occupational rehabilitation. The goal of occupational rehabilitation is to effectively use rehabilitated workers in their original occupation (sometimes with, sometimes without modification) or train them for new occupations. Careful and adequate training of qualified rehabilitated workers can achieve amazing results. New occupations should attempt to advance the workers and can be in *any* field as long as the workers are qualified. An unskilled textile laborer, unable to stand for long periods due to severe arthritis, was trained to be a skilled radio and television repairman (19).

The goal of Industrial Engineering is to optimize the man-machine system or the process. Any waste will prevent optimization. A capable, willing, and able rehabilitated worker without a job is a waste. It is the Industrial Engineer who can put him into the system most effectively.

INDUSTRIAL ENGINEERING TECHNIQUES IN OCCUPATIONAL REHABILITATION

The success of Industrial Engineering in our modern industrial society lies in its many and varied techniques. These same techniques with only slight modifications can be applied to occupational rehabilitation for the effective and efficient integration of the rehabilitated worker into the industrial system. These techniques include items concerned with personnel (items 1-4), job design and improvement (items 4-7), equipment and product design (items 5-7, 12), management (items 8-10), and plant layout and maintenance (items 7, 11, 12) (3).

1. *Industrial Psychology*—The problems of industrial learning, environmental conditions, industrial unrest, morale, monotony, and fatigue. The Industrial Engineer must see that each worker is properly trained and that he is satisfied with his environment if the worker is to become an effective member of the work force. The rehabilitated worker must also be trained and integrated into the work force. Additional problems, which also must be solved, are introduced when he is hired. For example, he must be accepted by the other individual workers and he must feel that he is adequately performing his own job.

2. *Industrial Sociology*—The study of interpersonal relations between workers. Friction between workers, cliques, or informal groups can destroy efficiency. The rehabilitated worker has additional problems. He is different from the other workers. Care must be taken that he is accepted into the group.

3. *Counseling Psychology*—The use of counseling for the purpose of helping the worker to solve his problems or solving the worker's problems for him. A worker with problems, whether they are personal or industrial, cannot do his best. This is true for the ordinary worker and for the handicapped worker as well.

4. *Personnel Psychology*—The selection and placement of employees by tests of intelligence and special ability and the determination of job requirements. Personnel tests have long been the standard method of selecting the proper man for a specific job. This method consists of finding a test in which success correlates highly with job success. (That is, a man that will succeed on the test most likely will succeed on the job.) The drawback in this method is that only a limited number will pass a given test. The rehabilitated worker, like any other worker, can take the personnel test. If he passes the test and if he has the physical capabilities of performing the job, he will have just as much chance of succeeding on the job as any other worker.

5. *Engineering Psychology*—The study of human stereotype reactions in order to simplify design problems and to simplify machine operations. Though it is seldom realized, there are stereotype reactions to certain conditions. "Up" on a light switch is on. A "clockwise" turn of a valve should close it. When these stereotype reactions are used in design of equipment, it becomes simpler for the workers to operate the machines. A rehabilitated worker also has stereotype reactions, which are the same as those of the ordinary worker, unless his handicap interferes.

6. *Human Engineering*—The incorporation of the stereotype reactions into an equipment design. In the past, workers have often been chosen for particular jobs by means of tests. A far better method would be to design the job (that is, the machine) so that everyone could perform or operate it. The use of stereotype reactions can be used in developing jobs for handicapped workmen. Reactions are divided among the senses: sight, hearing, feeling, tasting, or smelling. A man is handicapped when he loses part or all of one or more of these senses. However, fortunately the human body counteracts such losses by increasing the sensitivity of the other senses. For example, a blind man has a very highly developed sense of hearing and feeling; a deaf person learns to read lips. If this is remembered, a job can be modified so that the requirements of the lost sense can be replaced by one of the other senses.

7. *Time and Motion Study*—The application of work simplification to a process, to a group, to a machine, or to a man. Work simplification is a method for reducing wasted effort by dividing a process or a job into a series of increments and studying each one separately (5). Inefficient increments are dropped or revised. The process or job is then reassembled in the most efficient manner. Work simplification can also benefit the rehabilitated workers. Its methods provide an accurate means of determining whether or not the rehabilitated man can perform the job by testing each increment. It will also determine what modifications are necessary to fit the job to the rehabilitated worker.

8. *Labor-Management Relations*—The reduction of labor-management tensions by understanding and fairness on the part of all parties. Relations between management and the employees are governed by labor-management agreements, and by national, state, and local regulations. Friction must be avoided if productivity is to increase. Special regulations, like the Second Injury Law, control the use of rehabilitated workmen in some of the states. Unions as well as management and individual workers must accept the rehabilitated workers.

9. *Economics*—The study of profit-seeking organizations in a free society. Free enterprise depends upon a profit. No investment can be made unless a profit can be expected. No engineering change can be made unless it is economically feasible. Likewise, there should be no economical disadvantage in hiring handicapped workers. If management could be shown that there will be no loss of profits when they hire the handicapped workers, they would be more willing to accept them. A properly placed rehabilitated worker is as productive as any other worker. In addition, studies by welfare departments have shown him to be more dependable and willing than most of his coworkers.

10. *Industrial Management*—The use of efficient management and leadership and its methods for the control in industry. A good management is an efficient management. It is not led but leads. It knows how to make the best use of all its employees.

11. *Safety Engineering*—The use of proper safety precautions to insure maximum production. Accidents disrupt production as well as create heartaches. The Industrial Engineer should make every job a safe job. The use of a rehabilitated worker should never increase the possibility of job hazards. The engineer should be sure that the rehabilitated worker will not be in any danger of harming himself, his fellows, or the machinery.

12. *Design Engineering*—The proper design of machines, jobs, processes, and plants by a qualified Industrial Engineer is the best method of insuring a high degree of efficiency. The engineer can help the rehabilitated workers by designing machines that are simple to operate or that can be modified for the rehabilitated worker. When designing a job, only those requirements that are actually necessary should be listed. It would then be far easier to determine whether the rehabilitated worker can perform those duties or not.

SCIENTIFIC METHODOLOGY IN OCCUPATIONAL REHABILITATION

Other fields of endeavor, such as psychology, business administration, economics, and mechanical engineering, make use of one or more of the above techniques, but only Industrial Engineering uses all of them. Industrial Engineering applies these techniques in the proper manner by using scientific methodology in problem solution. These rules of scientific methodology can be applied to solving the problem of using rehabilitated workers (2). For example:

1. *Select the problem*—Choose a suitable job.
2. *Collect data*—Find out how the job is presently performed.
3. *Analyze the data*—Determine all the actual job requirements (that is, use of both hands), but be sure not to list any unnecessary requirements (that is, use of legs in a sitting job).
4. *Formulate a solution*—Can a rehabilitated worker perform the job? Certain handicaps may be allowable, others may not. Also, what modification or modifications can be made in the job to allow a rehabilitated worker to perform the work.
5. *Apply and follow up*—Hire a rehabilitated worker for the position. Determine his success and then hire others.

NEW JOBS FOR THE HANDICAPPED

The biggest need in occupational rehabilitation is finding additional jobs for the rehabilitated workers. There are three means by which such workers can be provided with new jobs (3).

ADAPTING THE HANDICAPPED TO EXISTING JOBS

Personnel, interest, and psychological tests should be used to determine if the rehabilitated worker has the interest and ability to perform the required duties. A list should be made of *all* the necessary requirements for the job, and the worker should fulfill these requirements just like anyone else. The requirements may be in the form of a check list for the physical activities, which include such items as walking, climbing, stooping, lifting, and pulling, and for the working conditions, which include such items as hot, humid, noisy, and moving objects (20). The personnel department should contact the other workers to insure that the handicapped worker will be accepted. A motion study should be made to show that he can carry out all the components of the job (5).

Even cases of extreme disabilities have been placed by the "check list" technique. A prospective student nurse, found to have advanced bilateral tuberculosis, was forced to give up her goal because of the strenuous work involved in nursing patients. She was placed, instead, through the "check list" technique in the drug room of a hospital as a technician (19).

MODIFYING EXISTING JOBS TO FIT THE HANDICAPPED

Personnel, interest, and psychological tests again should be used to determine if the rehabilitated worker has the interest and ability to perform the duties. A motion study should be made of the job in order to determine what modifications will be required. The design engineer should determine if these modifications can be made. The engineer should then determine the costs of the changes. These costs must be balanced by the advantages of hiring a rehabilitated worker—free testing and training by federal and state welfare services, good safety records, willingness to learn, and high rate of dependability.

Many existing jobs could presently be modified to fit rehabilitated workers if only someone were able to show management how simple it would be to make these changes and the economic advantages involved. Engineers have modified automobiles for leg amputees for many years. Architects have designed hospitals to accommodate wheel chairs. Similar modifications can be made in industrial vehicles (that is, tractors), business offices, and plants (17) (19).

CREATING NEW JOBS FOR THE HANDICAPPED

The best time to find jobs for the handicapped is when the plant is under construction, before the first man is hired. A combination of design and human engineering

in this stage could create many new jobs for rehabilitated workers. If the design engineer would only list the actual requirements when the job is first conceived, it would be found that the rehabilitated worker could handle many of these jobs. The author once visited a film packaging plant and observed girls with perfectly normal vision packaging film in completely dark rooms. Vision should never be a requirement for this particular job. A blind person could perform it just as well. Likewise, one sense can be used to replace another. If a man cannot hear, he should not be denied a job on a machine simply because the warning mechanism is a buzzer. The buzzer can be replaced by a flashing light.

The basic concept of Industrial Engineering is the equal importance of man, equipment, and materials. It ideally prepares the Industrial Engineer for occupational rehabilitation work. His techniques of personnel, job design and improvement, equipment and product design, management, and plant layout and design can all be applied in the three means for discovering and creating new jobs for the handicapped. The Industrial Engineer can use the scientific method of problem solution to determine whether or not the rehabilitated worker is suited for a particular job.

CONCLUSIONS

Engineering has still to play an important part in occupational rehabilitation. Industrial Engineering, with its interest in the human link, is best qualified for leadership in this work. Industrial Engineers should attempt to use rehabilitated workers whenever possible. Rehabilitation organizations state that it pays to hire the handicapped. Studies of the abilities, willingness, and dependability of well placed rehabilitated workers prove this statement.

The Industrial Engineer should not, however, be satisfied with using only one rehabilitated worker. Frank Gilbreth, who used time study in "The Search for the One Best Way," always remembered that for each new method he devised, that there was another still better way (6). Likewise, the Industrial Engineer should not be satisfied with the first attempt to use the handicapped. Constant application of the Industrial Engineering techniques will promote the use of many rehabilitated workers.

REFERENCES

(1) Bulova, Arde, "A Pattern for American Industry," an address before the President's Committee on Employment of the Physically Handicapped, August 27, 1954.

(2) Heyse, Herbert W., "Group Participation in Application of Work Simplification," an address before South Carolina Vocational Rehabilitation Workshop, Columbia, South Carolina, March 31, 1960.

(3) Heyse, Herbert W., "Industrial Engineering Techniques for Occupational Rehabilitation," and address before South Carolina Vocational Rehabilitation Workshop, Columbia, South Carolina, March 30, 1960.

(4) Hilton, Conrad N., "Hiring the Handicapped Pays," an address before the 30th Annual Convention of the National Society for Crippled Children, Chicago, Illinois, November 13, 1953.

(5) Niebel, Benjamin W., *Motion and Time Study*, Richard D. Irwin, Inc., Homewood, Illinois, 1955.

(6) Spriegel, William R., and Meyers, Clark E. (Editors), *The Writing of the Gilbreths*, Richard D. Irwin, Inc., Homewood, Illinois, 1953.

(7) Waldrop, Robert S., "Signs of the Times in Rehabilitation," *Journal of Rehabilitation*, Vol. XXV, No. 2, March-April, 1959, pp. 4-5.

(8) Weston, Austin, "Summary of the Industrial Engineering Symposium, Cornell University, October, 1955," *Journal of Industrial Engineering*, May-June, 1956, pp. 98-100.

(9) American Federation of Labor and Congress of Industrial Organizations, "Cooperation . . . the key to jobs for the Handicapped."

(10) American Heart Association, "The Facts about Employment and Heart Disease."

(11) Employee Relation Division, National Association of Manufacturers, "Hiring Handicapped People."

(12) The National Association of Mutual Casualty Companies, "The Handicapped Man for the Job—The Job for the Handicapped Man."

(13) Office of Vocational Rehabilitation, U. S. Department of Health, Education and Welfare, "Help for the Disabled through Vocational Rehabilitation."

(14) The President's Committee on Employment of the Physically Handicapped, "Key to Independence."

(15) South Carolina Vocational Rehabilitation Department, State Agency of Vocational Rehabilitation, "An Investment in our Disabled."

(16) South Carolina Vocational Rehabilitation Department, State Agency of Vocational Rehabilitation, "Legislator Tells of Our Rehabilitation; Praises Work of Program," *New Horizons*, Vol. 2, No. 1 (January 1961), p. 4.

(17) South Carolina Vocational Rehabilitation Department, State Agency of Vocational Rehabilitation, "Regional Case of the Year Award Won by Walterboro Counselor," *New Horizons*, Vol. 2, No. 3 (May, 1961), pp. 1, 3.

(18) South Carolina Vocational Rehabilitation Department, State Agency of Vocational Rehabilitation, "Story of Jimmy Sanders Chosen as Case of the Year," *New Horizons*, Vol. 1, No. 2 (May, 1960), p. 4.

(19) South Carolina Vocational Rehabilitation Department, State Agency of Vocational Rehabilitation, "Technical Service Files."

(20) State Employment Service (Affiliated with the United States Employment Service), "Ready, Willing and Able."

New Measurements to Determine the Effect of Task Factors on Body Member Acceleration Patterns

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FOR MANY YEARS knowledge of how to reduce and optimize human effort has been sought. However, quantitative study of human effort has been greatly hindered by the fact that no satisfactory definition of the term "effort" has been established. Although the term is frequently used in common speech, it has a weak operational meaning. Specifically, the following problems have not been adequately solved with respect to human effort:

1. What is to be measured.
2. What is to be the standard amount.
3. How the measurement is to be accomplished.

For purposes of this study, Ryan's definition of effort will be used. He refers to it as "*the relation between actual rate of performance and the capacity of the individual at a given time.* Effort involves energy, but it also involves other things, so that the two terms should not be equated or confused (21)."

Some of the earliest systematic observations on effort and human movements were made by Leonardo Da Vinci in the fifteenth century, and are described in his notes on the human body. In these notes, methods of accomplishing specific tasks were presented which minimized or optimized the human effort involved (20).

More recently an effort has been made to develop "objective measures" for the measurement of effort. One of the first objective measures used was time. Use of time as an objective measure assumes that the amount of time required to accomplish a task is related to the total effort required. All other factors remaining the same, a decrease in time would result in a decrease in total effort. Although time can be measured relatively accurately and objectively, it frequently proves to be inadequate as a measure of total effort, primarily because of the lack of a measure or control of the other factors involved in effort. In many cases the reduction in total effort due to decreased time is offset by a greater increase in effort due to other factors.

Other measures were sought which would reflect changes in factors other than time. One general approach assumed that the tangible physical components of a job would be related to the energy requirements, therefore providing an objective measure of effort. Such things as weight lifted, distance carried, and number of occurrences per day could be easily measured and combined into algebraic formulas in an attempt to provide an objective measure of effort.

The mechanical work formula has been used as a measure of human work. In this formula "work" is defined as force times distance (where distance is to be measured in the direction of the force vector), and "energy" is defined as work performed in a specific time (foot-pounds per second, minutes or hours). These very definitions limit the usefulness of this system for measuring human work. In an attempt to obtain a more realistic measure of effort, modified versions of the mechanical work formula which utilize nonlinear relationships between force and distance have been developed (12). Although more reasonable results can be obtained by use of a modified work formula, the same basic limitation of the mechanical work formula exists.

Other approaches to measurement of effort assumed that the amount of applied force is a basic contributor to effort. The "tension time" concept, originally defined by Hartree and Hill, utilizes the product of force (tension) and time measurements. Hartree and Hill emphasized that tension time is an important mechanical property of muscle and that it is closely related to the muscle's heat production (22).

Starr proposed a measure of human effort which is an extension of the tension time concept. The proposed system of measurement is based on a modification of the expression known to physicists as linear impulse. The integral of mass times acceleration with respect to time is utilized to provide the objective measure. By includ-

ing gravitational acceleration in this formula, Starr succeeded in expressing static work and dynamic work in similar terms. Although this measure is only an estimate of work done on a load it is in many instances closely related to one's subjective estimate of effort required.

The Lauru force platform (2) (13) has been suggested as an effective method of studying effort by analysis of forces. With this platform it is possible to compare the forces required by different jobs and methods. The platform has been used in the design of equipment by determining optimum size, shape, type and location of controls and handles to be used by the equipment operator. The Lauru platform provides an accurate continuous measure of forces exerted by the body. However, the relationships of these forces to the concepts of work measurement are not completely understood.

Based on the idea that the human body utilizes energy to develop force, various measurements of energy expenditure have been developed. Direct and indirect calorimetry have been employed in many studies of human work. Certain principles of motion economy have been verified and optimum methods have been determined on the basis of calorimetry measurements (9) (10) (15) (23).

Nadler has proposed an *a priori* procedure using energy expenditure calculations for finding the optimum motion pattern for a given task (17). This method bases the determination of energy expenditure upon kinetic energy. A mathematical and geometrical determination of body member movement eliminates the need for motion pictures. This biomechanical procedure yielded an optimum method of performing a simple task which was in agreement with a previous experiment performed (on the identical task) to determine the optimum method on a minimum time basis.

In addition to energy expenditure, other factors contributing to effort are known to affect the body metabolism. Various metabolic measurements have thus been explored in an attempt to provide some objective measure of effort. Heart rate, pulse rate, heart volume, circulation rate, steroid, lactic acid and carbon dioxide concentration, sweat rate, electrical resistance of the skin, pulmonary ventilation, and body temperature are some of the metabolic functions that have been studied (2) (4) (19) (24).

In rating, the measurement of effort is very important. The Westinghouse or leveling system was one of the first real attempts in rating to define factors affecting work performance (14). In this system, skill and effort are the factors to be measured; however, since no complete measure for these factors has been developed, judgment is required to obtain the values.

Speed rating was the next general attempt to measure the effects of factors affecting work performance (1) (3). In this system, the actual speed of body members was to be rated by judgment.

It has been suggested that average velocity of a body member is not the correct guide to use to judge pace, but that what must be judged is the rate of acceleration near the inception of the movement and the rate of deceleration near the conclusion of the movement (16) (17).

It is interesting to note that in spite of all the various "objective measures" that have been developed, rating methods depend primarily upon human judgment of body member motions. If human judgment is to be replaced by objective measures it is essential that body member motions receive further study.

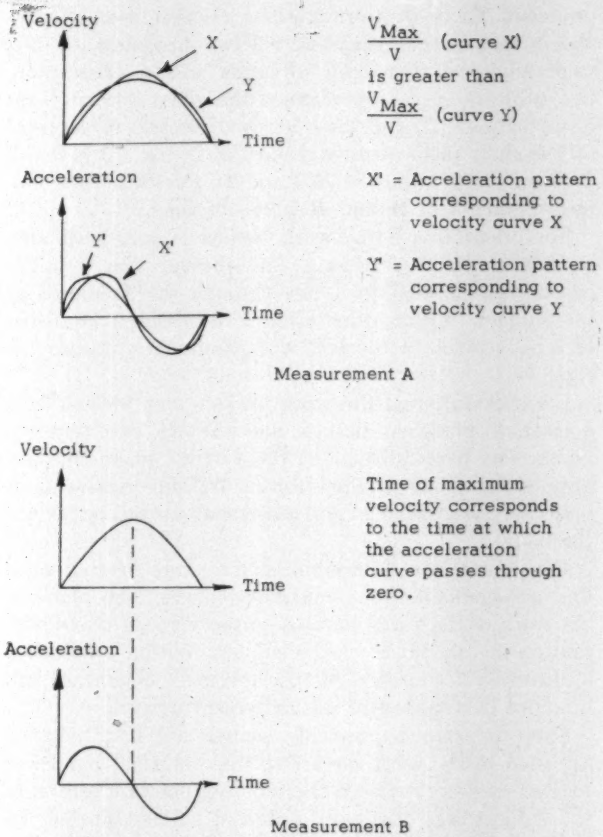
It is necessary to measure, in all their variations, the motions performed by people because these motions are the final result of all causal factors affecting physical work. To date, research and industrial techniques have determined only time between two points for a motion (by time study, kymograph, etc.), or a rough approximation of the motion-path (by motion pictures, chronocyclograph, etc.). Very little has been learned about what happens between the points, or how to translate a rough motion path presentation into the measurements needed for a motion (18).

Inherent in any manual task involving movement is a requirement of acceleration (and deceleration). This acceleration requirement plus the total mass to be moved determines a force, F, required of the muscles. Two basic contributors to total effort are, therefore, the amount of force, F, required and the length of time, dt, that the force must be applied. The term Fdt (or $madt$) is a single measure of these basic contributions to total effort. F and dt are interrelated and, for any given task, various combinations of F and dt could accomplish the task. The specific combination of F and dt actually chosen by the body to complete the task is the result of *all* factors involved. This particular combination should be revealed in the body member acceleration pattern. (See Figure 1 for an illustration of different patterns.)

Specifically, this investigation is an attempt to determine the effect of direction, weight handled, pace and gravity on the acceleration pattern of the right arm. The UNOPAR (8) will be used to provide acceleration pattern data.

DEVELOPMENT OF NECESSARY MEASUREMENTS

Before body member acceleration patterns can be studied, some definite measure of these patterns must be developed. In this study an acceleration curve is defined as a plot of acceleration (and deceleration) versus motion time. Similarly, an acceleration pattern is defined as an acceleration curve, with acceleration expressed as a percentage of peak acceleration and time expressed as a percentage of total motion time. An acceleration pattern is therefore a standardized curve which will not reflect differences in amount of time or amount of acceleration,



$\frac{V_{Max}}{V}$ (curve X) is greater than $\frac{V_{Max}}{V}$ (curve Y)

X' = Acceleration pattern corresponding to velocity curve X

Y' = Acceleration pattern corresponding to velocity curve Y

Time of maximum velocity corresponds to the time at which the acceleration curve passes through zero.

FIGURE 1. Acceleration Pattern Measurements.

but will reflect the distribution of total acceleration with respect to total time. A complete measure of an acceleration pattern could become very detailed and lengthy.

At the present time total acceleration curves for three dimensional body motions are difficult to obtain. The basic output of UNOPAR consists at present of a separate plot of velocity versus time for each of the three dimensions. To obtain total velocity a vector summation is required; to obtain a total acceleration curve the total velocity curve must be differentiated. However, since velocity is a direct result of acceleration some knowledge of acceleration patterns can be gained by studying velocity curves. For example, we know that the velocity of a motion reaches a maximum at the same instant that the acceleration curve passes through zero. If average velocity and maximum velocity are both known for a given motion, then additional knowledge of the acceleration pattern can be obtained. For example, if the ratio of maximum to average velocity changes between motions then we definitely know that the velocity pattern and therefore the acceleration pattern has changed. Based on the direction of change in this ratio (increase or decrease) we can determine in what general manner the acceleration pattern has changed. If the ratio has increased, a smaller proportion of the total acceleration (and deceleration) is taking place near the beginning (and end) of the motion. For this study the two following measures will be utilized to detect fundamental changes in acceleration patterns:

$$Measurement\ A - \frac{\text{Maximum Velocity}}{\text{Average Velocity}} = \frac{V_m}{\overline{V}}$$

Measurement A indicates the distribution of acceleration (and deceleration) with respect to the percent of total motion time. If a higher proportion of acceleration (and deceleration) occurs near the beginning (and end) of a motion the ratio, $V_m/\overline{V}$ will *decrease*. (See Figure 1)

$$Measurement\ B - \frac{\text{Time of Maximum Velocity}}{\text{Total Motion Time}} = \frac{t_{v_m}}{t_t}$$

Measurement B indicates the percentage of total motion time spent in acceleration. If a higher proportion of total motion time is spent in acceleration, the ratio t_{v_m}/t_t will *increase*. (See Figure 1)

It is felt that with the aid of UNOPAR a study of the change in acceleration pattern due to changes in specific factors contributing to effort will provide increased insight into work and create a foundation for developing better measures of human effort.

EQUIPMENT

A work surface containing two terminal points separated by a distance of 15 inches was used to describe a specific task (Figure 2). The task consisted of moving the right hand between the terminal points. Requirements for the satisfactory completion of the task include

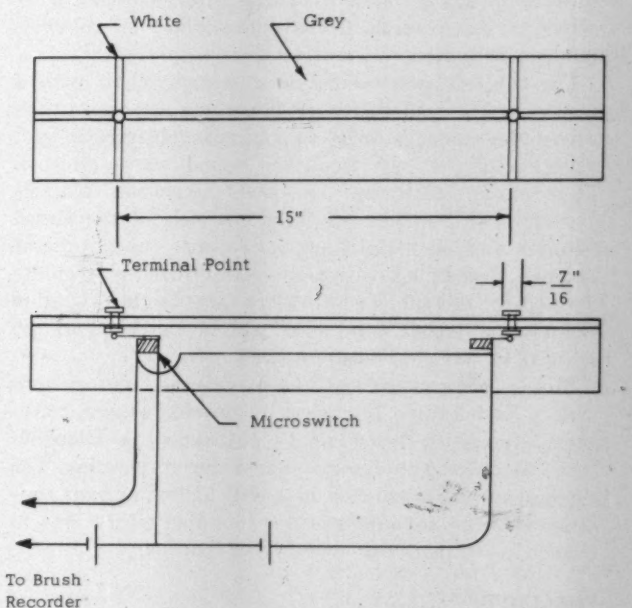


FIGURE 2. Design of Work Surface.

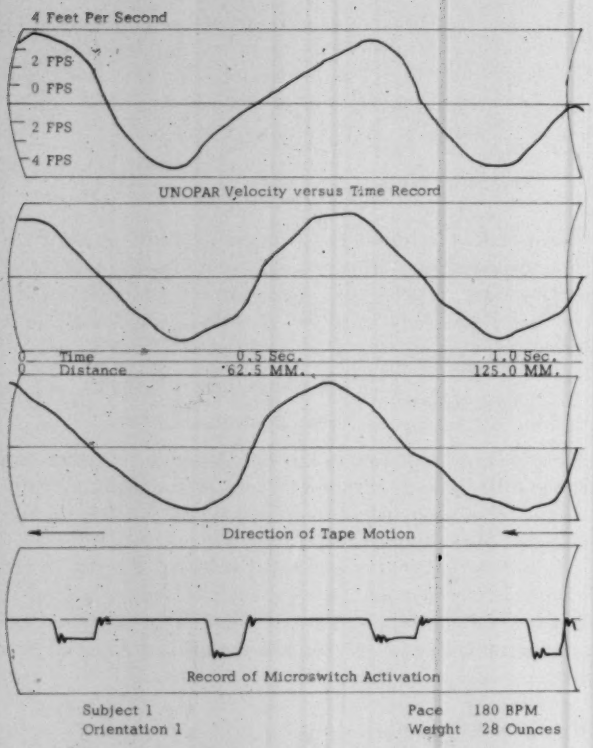


FIGURE 3. Sample Brush Recorder Output.

the activation of the terminal point microswitches at the beginning and end of the motion. The microswitches were connected to one channel of a Brush recorder. Since there was a different voltage through each microswitch, it was possible to determine which microswitch had been activated.

The subjects were seated in a straight chair with a back rest. The UNOPAR transducer was attached to the top of the subject's wrist to minimize obstruction and reflection of the high frequency sound waves emitted. The velocity component in each dimension was simultaneously recorded on three channels of the Brush recorder and on three-channel magnetic tape. A Seth-Thomas mechanical metronome was utilized to regulate the pace of the subjects. Small rectangular lead weights about three inches long were held in the hand of the subjects to vary the weight handled.

Motion pictures were taken of each task performance with a Kodak Cine II camera to provide general reference information which might be needed. A telephoto lens was utilized to minimize error due to parallax. The experiment was conducted in a well lighted and air conditioned room to minimize any possible effects due to change in temperature, humidity or lighting.

PROCEDURE

A complete factorial design was utilized in this experiment. Three task orientations, O, were used. Nested within each task orientation, the two directions, D (O), were analyzed. For each direction within orientation, two subjects, S, each performed the given task at three levels of pace, P, and three levels of weight, W. A total of 108 data plots resulted from the $2 \times 2 \times 3 \times 3 \times 3$ factorial design (see Tables 1 and 2). For each data plot, measurements of A and B were obtained.

For orientation 1 the work surface was located in a horizontal plane so that a line through the terminal points was parallel to a line through the shoulders of the subject. Within orientation 1, direction 1 consisted of a movement to the left, and direction 2 was to the right.

For orientation 2 the work surface was located in a horizontal plane so that a line through the terminal points was perpendicular to the vertical plane containing the shoulders of the subject. Within orientation 2, direction 1 consisted of the movement inward or toward the body.

For orientation 3 terminal points were located on a line perpendicular to a horizontal plane. The plane of the work surface was parallel to the vertical plane containing the shoulders of the subject. Within orientation 3, direction 1 consisted of the movement downward and direction 2 consisted of the movement upward.

Subjects were comfortably seated and their position adjusted to the work surface so that the right hand was located halfway between the terminal points. Position of the subject was vertically adjusted so that during the average arm position, the hand was slightly lower than the elbow.

Pace was regulated by the metronome at specific levels of 90, 135, and 180 beats per minute (or tasks per minute). Weight handled was varied between three specific levels of 0, 14, and 28 ounces.

Each subject completed the task approximately 1600 times during a practice period. During the practice period and during actual test runs a record was kept of the number of tasks completed correctly and the number of tasks attempted for each subject. Correlation between factor combinations due to sequence of factors was eliminated by using a random numbers table to determine the task sequences.

To determine total velocity from the three velocity component curves (see Figure 3) a vector summation was required. For a given task the one-half centimeter area containing maximum velocity was first located by visual inspection on the Brush recorder output. Values were then taken from each velocity component curve at four points equally spaced within the area containing maximum velocity. Total velocity was then calculated for each of the four points, based on a vector summation. The maximum of these total velocities was taken as maximum velocity for the task and the corresponding time was taken as the time of maximum velocity. Three

TABLE 1

Measurement A

Maximum Velocity

Average Velocity

			O_1		O_2		O_3	
			D_1	D_2	D_1	D_2	D_1	D_2
		P_1	1.59	1.46	1.55	1.43	1.85	1.56
	W_1	P_2	1.65	1.49	1.49	1.47	1.67	1.64
		P_3	1.41	1.48	1.53	1.44	1.70	1.47
		P_1	1.53	1.42	1.53	1.55	1.60	1.56
S_1	W_2	P_2	1.50	1.36	1.57	1.45	1.50	1.59
		P_3	1.41	1.42	1.49	1.43	1.55	1.53
		P_1	1.50	1.49	1.47	1.46	1.80	1.62
	W_3	P_2	1.37	1.35	1.44	1.44	1.47	1.65
		P_3	1.32	1.36	1.52	1.37	1.53	1.42
		P_1	1.56	1.45	1.46	1.45	1.49	1.62
	W_1	P_2	1.49	1.49	1.28	1.28	1.55	1.49
		P_3	1.38	1.38	1.24	1.32	1.59	1.44
		P_1	1.58	1.45	1.28	1.25	1.59	1.61
S_2	W_2	P_2	1.44	1.58	1.28	1.27	1.60	1.51
		P_3	1.33	1.42	1.26	1.25	1.61	1.42
		P_1	1.53	1.51	1.31	1.28	1.59	1.60
	W_3	P_2	1.40	1.46	1.28	1.25	1.68	1.56
		P_3	1.30	1.34	1.31	1.25	1.53	1.45

sets of measurements A and B were obtained for each task combination and the resulting averages were used in the calculations.

The statistical significance of the effects of experimental factors on measurements A and B was determined by analysis of variance. Orthogonal comparisons were used for further analysis of linear and quadratic components within the pace and weight factors. Actual calculation of measurements A and B, and sums of squares was performed by the IBM 650 data processing system.

RESULTS

The basic data used in variance testing are shown in Tables 1 and 2. The average ratio of maximum velocity to average velocity for the entire experiment was 1.47 (Measurement A). The average value of percent time spent in acceleration was 51.8% (Measurement B).

1. All three orientations have a highly significant difference with respect to measurement A. Orientation 3 was the largest and orientation 2 was the smallest in measurement A. No significant difference was found in measurement B due to orientation.

2. Within orientation 3, direction 2 was significantly smaller than direction 1 in measurement A. Within orientation 3, direction 2 was significantly greater to a high degree than direction 1 in measurement B.

3. Subjects had a highly significant difference in measurement A and B. Subject number 2 had the smallest measurement A and largest measurement B. Subject and orientation interaction was highly significant.

4. Pace had a highly significant effect on measurements A and B. With increase in pace, measurement A decreased linearly and measurement B increased linearly (Figure 4). The interaction between pace and direction within orientation was significant in measurement B. Although some significance was found in each orientation, the most definite significance was in orientation 3. In all orientation and directions a trend existed for an increase in measurement B with increased pace.

5. Weight had a significant effect on measurement A. With increase in weight, measurement A decreased linearly (Figure 4). The interaction between weight and direction within orientation was highly significant in measurement B. This significance was located only in orientation 3. In orientation 3 an increase in weight linearly *decreased* measurement B in the downward direction. In the upward direction, increased weight tended to *increase* measurement B.

6. Although not statistically significant, an interesting trend was found in the pace-weight interaction. A given increase in weight caused a constantly greater reduction in measurement A as pace increased. A given increase in pace caused constantly less reduction in measurement A as weight increased.

CONCLUSIONS

The following limitations apply to the conclusions obtained from this experiment:

1. All data in this experiment were obtained from two male subjects.

2. The subjects used were volunteers from the senior Industrial Engineering class and no attempt was made to obtain "average" subjects.

3. The experiment consisted of right hand activity only.

4. The basic task studied consisted of a simple motion containing a minimum of inherent difficulty factors.

5. Pace was limited to three specific levels of 90, 135 and 180 beats per minute. Weight handled was limited to 0, 14 and 28 ounces.

6. All arm motions were measured at a point directly on top of the subject's wrist. This required the use of a different distance factor for each orientation (6).

The following may be concluded within the above limitations:

1. Acceleration patterns of different people are affected in the

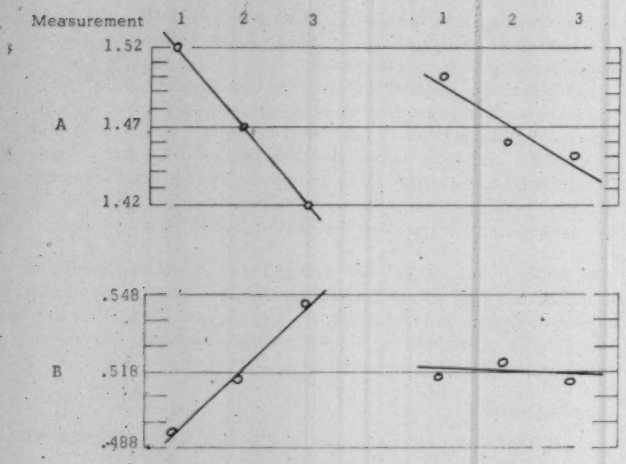
TABLE 2

Measurement B

Time of Maximum Velocity

Total Time

			O_1		O_2		O_3	
			D_1	D_2	D_1	D_2	D_1	D_2
		P_1	.552	.482	.407	.603	.476	.408
	W_1	P_2	.522	.463	.510	.555	.589	.437
		P_3	.467	.498	.539	.532	.608	.509
		P_1	.460	.465	.443	.537	.558	.438
S_1	W_2	P_2	.552	.495	.500	.545	.522	.427
		P_3	.490	.539	.566	.539	.568	.513
		P_1	.494	.478	.481	.472	.456	.486
	W_3	P_2	.558	.516	.523	.509	.493	.474
		P_3	.566	.549	.547	.546	.508	.499
		P_1	.552	.532	.465	.515	.624	.405
	W_1	P_2	.471	.493	.512	.526	.574	.486
		P_3	.587	.618	.581	.556	.590	.482
		P_1	.505	.497	.486	.594	.563	.492
S_2	W_2	P_2	.571	.483	.506	.503	.554	.499
		P_3	.545	.600	.563	.551	.633	.512
		P_1	.499	.515	.506	.497	.481	.481
	W_3	P_2	.588	.504	.554	.487	.548	.496
		P_3	.534	.507	.570	.527	.580	.476



	Pace			Weight		
	1	2	3	1	2	3
Measurement A	1.52	1.47	1.42	1.50	1.46	1.45
Measurement B	.494	.515	.544	.517	.522	.514

FIGURE 4. Effect of Pace and Weight versus Measurements *A* and *B*.

same general manner by pace, weight, direction and gravity.

2. Acceleration patterns between individuals can be expected to differ significantly because of individual differences.

3. Weight handled and direction of motion (relative to the gravitational force) significantly affect measurement *A* of the body member acceleration pattern. Pace also has a highly significant effect on measurement *A*. Increases in pace or weight decrease measurement *A*. An increase in the amount of gravitational force in opposition to body member acceleration also causes a decrease in measurement *A*.

4. Pace has a highly significant effect on the percent time spent in acceleration (measurement *B*). Increased pace results in increased percent time spent in acceleration *regardless* of orientation or direction.

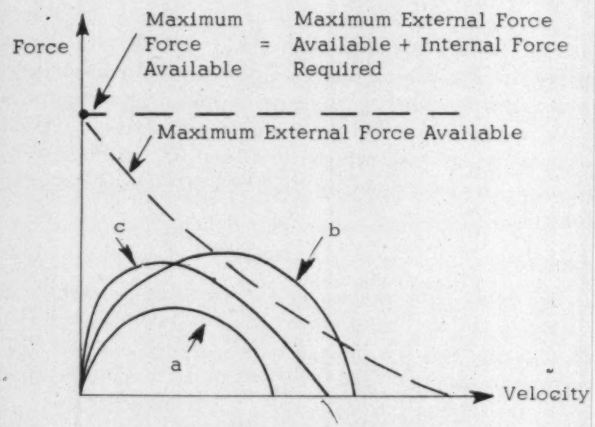
5. Direction (relative to the gravitational force) has a highly significant effect on the percent time spent in acceleration (measurement *B*). The percent time spent in acceleration is less when acceleration and the gravitational force are in opposition. When acceleration is aided by the gravitational force the percent time spent in acceleration is *greater*.

6. The interaction of weight and direction (relative to the gravitational force) has a highly significant effect on the percent time spent in acceleration. However, weight alone has no significant effect on this measure. When gravity aids acceleration, increased weight decreases the percent time spent in acceleration. When gravity and acceleration are in opposition, increased weight increases the percent time spent in acceleration.

DISCUSSION

This experiment has shown that a body member chooses different acceleration patterns for different levels of pace and weight and for different directions (relative to the force of gravity). An explanation of why some change in acceleration pattern must occur is provided by findings of earlier research. Fenn established a relationship between the speed of muscular contraction and the loss in muscular tension which was valid at least for the conditions of his experiment. "For a rate of shortening of 10% of its length per second a muscle loses an average of 3.1% of its tension (5)." This means that the faster the muscle contracts, the less external force it can apply, and the limit is reached when the rate of shortening is about 32% of its length per second ($32/10 \times 3.1 = 99.2$). This relationship accounts very well for the changes in measurement *A*. For example, if for a given task the pace is increased to a maximum, a greater amount of acceleration *must* be put forth earlier in the motion (when the speed of muscular contraction is low) in order to accomplish the given task (Figure 5).

The significance of weight on acceleration pattern which was found in this experiment lends support to the conclusion reached by Gambrell in 1958. The results of his research indicated that one should *reject* the experimental hypothesis that, *"Ratings Made by Skilled, Thoroughly Trained and Practicing Time Study Analysts Using Pace Rating Are Not Influenced by Job Difficulty* (7)." Pace rating requires the rating analyst to judge the amount of acceleration near the inception of the movement and the rate of deceleration near the conclusion of the movement. Since the acceleration pattern is significantly changed by weight handled, ratings based on these acceleration patterns should also be expected to differ.



Force = Muscular Force = Mass × Acceleration.

Velocity = Rate of shortening of the muscle.

a = Typical plot of Force versus Velocity utilized in completing the given task.

b = Plot of Force versus Velocity yielding acceleration pattern equivalent to a, and capable of completing the given task at increased pace.

c = Plot chosen by body member to complete the given task at increased pace.

FIGURE 5. Effect of Maximum External Force Available on Choice of Acceleration Pattern.

Increases in pace or weight handled cause an increase in the difficulty of a task. This experiment found that an increase in any of these factors also causes a decrease in measurement *A*. The fact that subject 2 had consistently lower values than subject 1 with respect to measurement *A* indicates that subject 2 may have been working closer to his limit of the amount of external force available. Subject 1 was definitely more muscular than subject 2.

Although past research is capable of explaining why some change in acceleration pattern must occur, not enough evidence is available to provide an explanation of why a *specific* acceleration pattern is chosen in preference to other acceleration patterns that are available to the body member within the limitations of external force available. A possible answer to this question is that the body seeks a motion pattern to perform a given task that is *optimum* in light of all factors affecting the body, and that with training, the body member approaches closer to this optimum.

The results of this experiment with respect to measurement *B* are of particular interest since they contradict some present beliefs concerning the effect of pace on acceleration patterns. In recent literature (16) (17) it is stated that the percent time spent in acceleration remains the same regardless of pace. This experiment has shown that pace has a highly significant effect on the percent time spent in acceleration. In addition, direction (relative to the force of gravity), and the interaction of direction and weight also have a highly significant effect on the percent time spent in acceleration.

Such results can be explained in light of previous studies which have indicated that a given amount of deceleration can be accomplished by a body member more easily than the same amount of acceleration. Fenn reasoned that the internal loss due to muscular "viscosity" opposed acceleration, but aided deceleration (5). Very recent research supports even more strongly the proposition that deceleration requires less effort than acceleration. Based on a laboratory experiment, Hill states that work absorbed in stretching a contracting muscle can actually reverse the chemical process of muscular activity (11). If this is true, deceleration in effect "recharges" the muscle performing the deceleration.

This experiment has shown that in addition to such measurable quantities as time, calories, force in pounds, foot-pounds, and pound-seconds the body member acceleration pattern is closely related to factors contributing to effort. Additional research performed to establish the relationship between total effort, individual components of effort and the shape of the acceleration curve would be very profitable. Feasibility of such research will be greatly increased in the near future when analog computer equipment is incorporated into the UNOPAR. UNOPAR will then be able to directly provide accurate continuous plots of total velocity, total acceleration and displacement versus time.

REFERENCES

(1) Barnes, Ralph M., *Motion and Time Study*, Third Edition, John Wiley and Sons, New York, 1949, p. 399.

(2) Brouha, L. A., "Fatigue—Measuring and Reducing It," *Advanced Management*, Volume 10, No. 1, 1954, pp. 9–19.

(3) Carroll, Phil, *Time Study for Cost Control*, Second Edition, McGraw-Hill Book Company, New York, 1943, pp. 379–380.

(4) Consolazio, Johnson and Marek, *Metabolic Methods*, C. V. Mosby Company, St. Louis, Missouri, 1951.

(5) Fenn, W. O., Brady, H., and Petrilli, A., "The Tension Developed by Human Muscles at Different Velocities of Shortening," *American Journal of Physiology*, Volume 97, No. 1, 1931.

(6) Franz, D. R., "Effect of Pace, Weight and Direction on Body Member Acceleration Patterns," M.S.I.E. Thesis, Washington University, St. Louis, September 1960.

(7) Gambrell, C. B., Jr., "The Independence of Pace Rating Versus Weight Handled," *Journal of Industrial Engineering*, Volume 10, No. 4, 1959, p. 318.

(8) Goldman, Jay, "Development and Testing of an Electronic Method for Determining Acceleration, Constant Velocity and Deceleration of Body Motions," D. Sc. dissertation, Washington University, 1955.

(9) Greene, James H., Morris, W. H. M., and Wiebers, J. E., "A Method for Measuring Physiological Cost of Work," *Journal of Industrial Engineering*, Volume X, No. 3, p. 180.

(10) Halberstadt, H. J., "Determination of the Optimum Angle for a Work Area by Means of Metabolic Measurements, Plus Instrumentation," M.S. Thesis, Purdue University, 1950.

(11) Hill, A. V., "Production and Absorption of Work by Muscle," *Science*, Volume 131, No. 3404, 1960.

(12) Ingenohl, Ingo, "Measuring Physical Effort," *Journal of Industrial Engineering*, Volume X, No. 2, 1959, p. 99.

(13) Lauru, L., and Brouha, L., "Physiological Study of Motions," *Advanced Management*, Volume 22, No. 3, 1957 pp. 17–24.

(14) Lowry, S. M., Maynard, H. B., and Stegmerten, G. J., *Time and Motion Study*, McGraw-Hill Book Company, New York, 1940, p. 238.

(15) McCugh, R., "Time and Energy Relationships of One and Two Hand Activity," M.S. Thesis, Washington University, 1952.

(16) Mundel, M. E., *Motion and Time Study*, Second Edition, Prentice-Hall Inc., New York, 1955.

(17) Nadler, Gerald, *Motion and Time Study*, McGraw-Hill Book Company, New York, 1955.

(18) Nadler, Gerald, and Goldman, Jay, "The UNOPAR," *Journal of Industrial Engineering*, Volume IX, No. 1, 1958, p. 58.

(19) Nichols D. Edward, and Amrine, Harold T., "A Physiological Appraisal of Selected Principles of Motion Economy," *Journal of Industrial Engineering*, Volume X, No. 5, 1959, p. 373.

(20) Richter, Jean Paul, *The Literary Works of Leonardo Da Vinci*, Oxford University Press, London, 1939, pp. 243–270.

(21) Ryan, T. A., *Work and Effort*, Ronald Press Company, New York, 1947, p. 22.

(22) Starr, L., "Units for the Expression of Both Static and Dynamic Work in Similar Terms, and Their Applications to Weight Lifting Experiments," *Journal of Applied Physiology*, Volume 4, No. 21, 1951.

(23) Thorson, P., "A Metabolic Investigation of One-Handed versus Two-Handed Work," M.S. Thesis, Purdue University, 1951.

(24) Young, H. H., "Relation between Heart Rate and the Intensity of Work for Selected Tasks," *Journal of Industrial Engineering*, Volume 7, No. 6, 1956, pp. 300–303.

How Computer Specialists Can Help Lawyers

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THE WIDESPREAD adoption of computers throughout society is introducing highly technical factors into legal situations so extensively that lawyers soon will need assistance from computer specialists in unravelling facts, securing evidence, and planning strategy in many cases. Like other major technological innovations, the computer revolution is having a substantial impact on the legal process. Thus far, resort to computers is not affecting fundamental rules of law because the devices only represent new tools to accomplish familiar activities. That situation may change as more sophisticated use is made of computers. However, at present, computer technology requires special attention from the legal point of view because its mechanisms and techniques are more foreign to common experience and its impact is more extensive than preceding comparable innovations in our society. As a consequence, the legal significance of many factual aspects of the use of the machines for a variety of purposes is not recognized by most lawyers.

Of course, it is as important for persons working with and using computers, as it is for lawyers, to be aware of the legal implications of the devices. Forearmed in that way, those persons can take steps to avoid or minimize many costly legal entanglements. In a previous article, computer specialists were informed of some legal aspects of the technology of special concern to themselves (1). There, it was pointed out that the rules of negligence law, which cover accidents resulting in injuries, might require greater care than planned in setting up some computer systems where, considering only business factors, a company is willing to compromise and accept the risk of mishaps. It also was shown that the rules provide a persuasive argument for the adoption of computers of various types to detect, and possibly correct, hazards in order to reduce exposure to accidents. To make the most of the law, computer specialists were urged to secure legal advice on specific fact situations.

In this presentation, computer specialists will be informed of the many ways they, in turn, can help lawyers solve legal problems complicated by the new technology. As lawyers are confronted with bewildering fact situations in the wake of the accelerating pace of computer installations, computer specialists will have numerous occasions to be of help in dispelling the technical confusion. Because of the variety of computer applications, this work with lawyers will involve substantially all types of legal problems. As will be pointed out later in this article, the computer affected cases will run the gamut from simple actions to collect money for merchandise delivered to complex antitrust litigation, and will include a whole range of damage suits arising out of aircraft, train, and factory accidents.

Computer specialists can be of service to lawyers in two primary capacities. In one role, they can work behind the scenes as consultants, either on preventive projects to avoid legal entanglements or in connection with actual litigation in court. In the other, they can serve as expert witnesses in court.

The precise ways computer specialists can assist with legal problems can be understood best in the light of the different circumstances under which they might be called in by lawyers. When first presented with a legal question, for example, the lawyer may need help in identifying the facts tending to show whether or not his client was negligent, if that type of problem is involved. Later, he will welcome aid, in a wide variety of cases, in getting possession of evidence he will use to prove his own case or refute his opponent's. Ultimately, he might want to put the specialist on the stand as an actual source of evidence. The contribution the computer specialist can make in each of these types of situations will be explored successively in the balance of this article.

But first, a few general observations. The computer specialist should recognize that he can render a real service to the lawyer by dispelling any mystery that might exist about the devices. He should point out the fundamental simplicity of the technology, built as it is on a series of very elementary steps, and its complete lack of capacity to innovate, being completely dependent upon the instructions of the program. If the lawyer wants to capitalize on any unwarranted awe in which computers are held by a judge or jury, that is another matter entirely. He should do so as a strategist, with full awareness of reality.

FINDING NEGLIGENCE IN COMPUTER AFFECTED OPERATIONS

In situations where the use of a computer device is either the cause of or the means of preventing an accident, a lawyer will have to consider whether legal negligence exists. In reaching an opinion, he must know whether all reasonable precautions have been taken or planned to avoid a mishap. As indicated in the earlier article, he will consider whether "due care" has been exercised.

The lawyer can be faced with a wide variety of fact situations. For example, a computer controlled production operation may have run amuck, resulting in an explosion injuring nonemployees. If the lawyer is defending the company, he will want to show, if possible, that all possible error prevention and detection features in machine functioning, programming, and input were incorporated in the system and that the particular occurrence could not have been anticipated for all practical purposes. As a claimant's counsel, on the other hand, he will look for failures in those areas to provide for the contingency that eventuated.

In a completely different situation, the case may involve the claim that the accident could have been prevented by the use of an available computer device. For example, the use of a computer to check out structural strength of a new model airplane might have prevented a crash. Opposing counsel will dispute whether the device probably would have averted the accident and whether its effectiveness for that purpose had become recognized so generally that a reasonably prudent person would have used it.

As indicated, this question of legal negligence may arise not only after an accident has occurred but also during the planning stage of operations when preventive measures can be taken. Actually, the earlier it is considered, the greater is the chance of avoiding legal problems.

In practically all accident-type cases involving computers, lawyers will need help in assembling the relevant technical facts. They will depend greatly on persons familiar with the new technology. Because lawyers many times will not have the background to recognize either helpful aspects or pit-falls in the complex fact situations, the computer specialist called in should suggest important points on his own initiative.

HOW THE COMPUTER SPECIALIST CAN ASSIST IN DISCOVERY

During lawsuits, it frequently is possible for the parties, through their lawyers, to get evidence from each other in advance of trial by a procedural step known as discovery. This is a very important legal tactic that requires careful planning.

There are five major types of discovery tactics:

1. An order by the court, at the request of one of the parties, for the delivery of documents or other tangible things for inspection and copying.
2. A demand, called a *subpoena duces tecum*, for the delivery of documents at a hearing for use in interrogating a witness.
3. A series of written questions, called interrogatories, to be answered in writing, that might ask for facts or for the identification of records.
4. Oral questioning, called the taking of a deposition.
5. Written requests for the admission of the correctness of stated facts.

Frequently, even apart from the complexities of computers, the lawyer using discovery to secure recorded material does not know in advance what specific helpful items are in the possession of the opposing party and thus cannot describe them precisely. In those cases, he asks in a general way for all items that meet certain conditions, such as type of record, subject matter, period of time, author, recipient, and the like. For example, the lawyer would ask for all documents written, prepared, or received by officers or employees of a specified company between certain dates that refer or relate to a particular transaction, policy, or program. In defining the term "document," he would state all types of records intended to be included, referring not only to traditionally familiar letters, memoranda, minutes of meetings, and the like, but also to more recently utilized tape and wire recordings, photographs, and microfilms, and now to the even newer punched cards, magnetic tape and related recording media for computers.

The computer specialist can help the lawyer engage in discovery that might involve computer material in the following manner:

1. SUGGEST MATERIAL TO REQUEST

A computer specialist is needed to suggest computer related material that might exist, and should be requested, in order to prove facts considered by the lawyer to be important to his case. Those facts, of course, can be extremely varied. They might involve, for example, the basis for and amount of a debt, in a simple collection case; or a series of sales of merchandise, including names of customers, types of goods, and net prices, in an antitrust suit; or the knowledge that a machine was defective or the cause of an error in engineering design, in a suit for damages. Note that with increasing frequency computer material is evidence to prove those facts and others. That material might include, for example, the machine program; records created by a computer hazard inspection device; company records reflecting experience with a computer control system; written reports of the consideration given to the adoption of a computer; and business records maintained on a computer.

2. HELP DESCRIBE MATERIAL SOUGHT

In addition to identifying computer material that might be useful, the specialist should be able to help the lawyer describe, either generally or specifically, that material

sought in a discovery document. Since many lawyers for clients called upon to produce data interpret the language very narrowly in order to reduce its scope, unambiguous descriptions of material are essential. Technical computer terms, especially, should be selected with care.

The computer specialist also can help the lawyer decide on the form in which the requested data are to be produced. This is a novel consideration for lawyers because the traditional written records exist in only one form and offer no choice. For computer material, however, it must be stated whether the actual punched cards and magnetic or paper tape, or merely print-outs from them, are to be delivered. Because of the large amount of data included on a single tape or other magnetic record, the present method of asking for all documents that contain certain subject matter will cover substantial amounts of information on those media not properly pertinent, as well as the few items in point. If taken literally, such a request not only would impose a hardship on the supplier but also might make it difficult for the requester to find what he needs in the large mass of information. Of course, punched cards, being like individual written records, present no problem. They can be sorted to pick out the relevant ones.

If data on discs, cores, drums, and similar nonportable recording media are sought, undoubtedly the requesting party will have to be content with print-outs.

When tapes or punched cards are secured, specially printed manifold paper or forms may be necessary for the print-outs in order to make them understandable. If so, a supply of that paper or those forms also must be secured.

To forestall objections by the opposing party to compliance on the grounds of burdensomeness, the lawyer should know about the difficulty and expense of complying with his request. In addition to providing that information, the specialist should point out, where appropriate, the ease with which tapes and punched cards can be duplicated and printed out, and how outside machines, including service bureau equipment, can be used if a company's system is overburdened.

Of course, a computer specialist can help a lawyer resist a discovery request by singling out unclear descriptions of wanted material and steps involved that are unusually burdensome or unreasonable.

3. HELP IN UTILIZING THE MATERIAL SECURED

There are many ways the computer specialist can help the lawyer use the material secured by discovery. If tapes or cards are delivered, he can have print-outs made at a service bureau or other facility. He can interpret and explain data that have technical aspects. Similarly, he can evaluate the reliability of material from a computer system and suggest areas for investigation of accuracy of input or processing, of completeness, of the possibility of falsification, and the like. He also should inform the lawyer how magnetic tapes and punched cards should be stored and handled to avoid damaging them. Finally, he can instruct how to test the adequacy of compliance by the opposing party with the discovery step, if there is any doubt about it.

ASSISTING IN PREPARING QUESTIONS FOR WITNESSES

In many trials, witnesses will be called to testify on subjects relating to computers, and lawyers will need help in framing questions for them. Those questions may either bring out information helpful to the lawyer's case or, in cross examination, point out flaws in the testimony of witnesses for the opponent.

The witnesses might testify, for example, about the precautions taken to avoid an accident in a computer controlled operation, the results of calculations made on a computer, or the business records maintained in a computer.

The general approach in every situation will have to be selected by the lawyer. The computer specialist should suggest types of evidentiary material falling within the framework laid out and explain its significance and weaknesses, if any. It is especially important to anticipate any deficiencies that might be picked up by the other side, and thus avoid embarrassment.

Where computers are used to make mathematical computations, like statistical analyses, it should be explained to the lawyer that the devices themselves are merely the same type of tool as the more conventional adding machines and that the mere fact of their use does not introduce any problems. The important questions are whether the procedure carried out by the device is accurate and whether the underlying data used are correct and complete from a mathematical or statistical point of view. Both the general analytical procedure and the data should be the same as would have been used even if a computer were not involved.

ASSISTING IN SELECTING MEMBERS OF THE JURY

The presence of computer material in a case adds another consideration to be taken into account by the lawyer in selecting a jury. Although the names of jurors are drawn at random from a panel, each lawyer has certain privileges of rejecting prospects. For example, he may strike off the names of a limited number of jurors who, he feels, might have attitudes unfavorable to his case.

At present, computer technology represents a novel and mysterious force. It also has wide social implications as a factor in automation. Therefore, attitudes toward it also should be taken into account in selecting jurors. For example, antagonism toward a computer user might be expected from a person who was displaced by such a device, who is concerned about unemployment because of

automation, or who feels that its use dehumanizes work. A favorable reaction might be found in one who is intrigued by the new technology, who favors its use to eliminate drudgery, or who feels that its adoption is essential if many unusually voluminous operations are to be performed.

Through their work in planning and setting up new installations and from their other activities, computer specialists are aware of prevailing attitudes toward the devices. They can, therefore, render a real service to attorneys who must consider these attitudes in selecting jurors.

COMPUTER SPECIALIST AS A WITNESS IN COURT

There are many situations where a computer specialist might be needed as a witness in a trial. He might be called to present the results of a statistical analysis made on a computer.

In negligence cases, the specialist, at the request of a defendant, might describe the precautions taken in a computer control mechanism to show that they were all that could be expected. Or, aiding a plaintiff, he might tell about the availability of, and experience with, computer hazard detectors that might have been used to avoid a mishap. As the lawyer undoubtedly will point out at the time, an expert witness may describe usual practices and precautions so that the jury will be able to decide what steps the imaginary reasonable man would have taken and to evaluate the actual conduct, in that light.

In cases where it is suspected that some of the jurors might be antagonistic toward the use of computer devices, the testifying specialist might suggest counteracting evidence to the lawyer. For example, it might be possible to work into the testimony a brief discussion of how the particular computer system was essential to achieve lower costs and thus permit continuance of a necessary service; how sheer drudgery was eliminated; or how employees were upgraded.

When testifying, the computer specialist normally should use a simple style of presentation, devoid of the technical jargon he finds so meaningful in his own profession. At times, however, the lawyer might request some specialized terms to create an aura of scientific accuracy or even of mystery.

POSSIBLE CONFLICTS OF INTEREST

Should a computer specialist not be able to support wholeheartedly the position of the attorney consulting him, he should decline the assignment. For example, he might not feel free, because of past or current professional relations, to describe weaknesses in a particular device. However, this very point might be a critical element in the lawyer's case. Since the lawyer is entitled to objective technical advice and may not be aware of those conflicts of interest, the specialist must scrupulously avoid any such limitations on his objectivity.

COMPUTER SPECIALISTS SHOULD PREPARE FOR LEGAL TASKS

In the near future, lawyers probably will start calling on computer specialists to participate in some of the legal steps described. As the new technology is adopted more widely, inevitably it will be involved frequently in legal situations, and lawyers will need skilled assistance in working with it.

To be most effective, the specialist should have a general familiarity with legal rules and procedures. In addition, specialists will have to take initiative, when consulting with lawyers, to compensate for the inability of lawyers to appreciate the technical aspects adequately. However, the specialist should remember that ultimate responsibility for litigation rests on the lawyer. Therefore, the specialist should be guided by the lawyer's instructions, which will reflect the requirements of the situation.

REFERENCE

(1) Freed, Roy N., "Some Legal Aspects of Computer Use in Business and Industry," *Journal of Industrial Engineering*, July-August, 1961, p. 289.

I.E. OPPORTUNITIES SERVICE

NOTICE TO MEMBERS

The technicalities involved in modifying our present tax classification require the removal of the I.E. Opportunities Service Bulletin from the *Journal of Industrial Engineering* until further notice.

The AIIE Constitution changes must be approved by the membership and the tax application approved by the Internal Revenue Service before this service may be made available in the *Journal* again.

The I.E. Opportunities Service Bulletin will continue to be published on a monthly schedule for distribution to your chapter only. Inquiries from members based on a review of the bulletin will continue to be handled by the Institute headquarters.

J. F. Jericho, President

E. P. Lange, Executive Secretary

Comments on "An Experimental Evaluation of the Validity of Predetermined Elemental Time Systems"

by GERALD B. BAILEY[1]

Woods, Gordon and Company, Toronto, Canada

THE SCHMIDTKE-STIER report is worthy of careful study by everyone who is connected with the field of work measurement. In the main, the report is critical of predetermined motion time systems. At least the authors do not hold to the point of view of the groups of researchers who developed and put to use the three systems referred to in the report. It may be taken for granted, I believe, that representatives of BMT, MTM and WF, speaking either collectively or individually, will give less than full support to the findings of the report. At the same time, these representatives (of which I am one) would be open to criticism themselves if they were to reject the findings of the report out of hand while overlooking the fact that the existence of more than one predetermined time system at least implies a criticism of the other systems.

In the field of work measurement, as in many other fields, there is room for differences of opinion. And, as in other fields, there is more than one avenue to be explored in the search for the ideal measurement system. As new findings are reported upon, they should be carefully examined, not so much for the findings themselves (important as they may be) but initially for the methods used to develop the findings. If the research methods stand the test, the findings themselves will carry much weight.

In this vein it would appear to be proper to comment upon some of the procedures described in the report.

Before commenting on these procedures, it would also be well to recall that the original report was written in the German language and while the translation into English is no doubt an excellent one, there is a strong possibility that the exact meaning the authors wish to convey has in some instances been slightly altered. For this reason, it would appear to be appropriate to restrict comments to aspects of the procedures that can scarcely have been affected by translation.

One part of the procedures that falls into the latter category is the way the various tests were carried out.

Under accepted time study practice, the observed time for each person studied is adjusted by a pace rating (that is leveled) to produce a standard or normal time. When the standard times from three different people (the smallest number of subjects to take part in a test), studied separately, are identical, or nearly so, for the same activity, the times are likely to be accepted in most quarters as proper for the work. When as many as fifteen people (the largest number of subjects to take part in a test) are studied separately and the individual standard times, obtained under the same circumstances, are in close agreement, universal acceptance of the times is assured.

This is not the manner in which the tests were carried out, however. The times reported are actual times. The only element of control that was used was the request to each subject to work at the pace that was most comfortable for him. Under these circumstances it is not surprising to find quite substantial differences in the average times obtained for any given test. In Figure 9, for example, the range in average times recorded for seven subjects is such that the slowest subject took between 30% and 40% more time then the fastest subject. A similar range is shown in the times recorded in Table 1 for seven subjects. No doubt similar ranges were found in the results obtained from other tests.

The actual times that appear in Figure 9 and Table 1 are shown for other purposes, upon which I shall comment later. For the moment I should like to confine my remarks to the use of average times. An average time based on the results obtained from up to fifteen subjects can hardly be regarded as representative of all workers. How many subjects would need to be studied to produce results that form a normal distribution and thus an average time that would be representative of all workers? I do not know, but I would expect that the number would be closer to one or two hundred than to fifteen. Nevertheless the authors use average times obtained from a

[1] Coauthor with Ralph Presgrave of *Basic Motion Timestudy*, McGraw-Hill Book Company, Inc., New York.

very small number of subjects to form conclusions and to draw comparisons between their findings and the time data from three predetermined time systems.

It is entirely possible that, with a larger number of subjects from which to obtain average times, some of the results would change. The data from the predetermined time systems that now appear to differ by a large amount from the findings of the authors might then be in closer agreement. Or the differences might be even greater. Whether or not the relationships changed, time data based on the results obtained from a large enough number of subjects to form a normal distribution would be more acceptable.

My second comment refers to the way the recording device marked the break-off points between successive motions. I shall refer specifically to the test arrangement illustrated in Figure 19. In this test the subject moved a pencil-shaped pin back and forth between locations that were marked by metal discs. One location was marked by a single disc approximately one inch in diameter, the other by two discs, one being approximately one inch in diameter, the other being approximately one-eighth inch in diameter. The time information produced by the recording device indicated that the motion away from the small disc took more time than the motion away from the large disc although in both cases the motion away was toward a large disc. That is, the move away was the same physically in both instances. When different times for the identical actions appeared, the authors concluded that these times were influenced by the preceding motions, thus showing the interdependence of motions.

On the basis of the time information provided by the recording device, one cannot disagree with the conclusions arrived at by the authors. However, they would have obtained different results and arrived at different conclusions if they had used a different method of recording the end points of motions. If, for example, their recording device had been designed to indicate the start rather than the end of a motion, the extra time assigned to the motion away from the small disc would have been assigned to the previous motion, where it belongs. Then the motion toward the single disc, whether it started at the small or the large disc, would have produced a constant time.

Strong evidence that the extra time belongs with the time for the motion just ended (the previous motion) may be obtained from a series of tests that the authors could carry out quite handily. The first test would consist of moving the pencil-like contact back and forth without interruption over a measured distance to touch in turn small metal discs that mark the distance. From this test, the authors will obtain a time for a single motion to the small target. Provided the subjects who performed the test described in support of Table 19 also perform this test, the time for a single motion will be slightly higher now than the time for the corresponding motion derived from the earlier tests. The new time will now contain the extra time that was formerly assigned to the motion away. That is, the following motion.

The second test should be carried out in the same way using the large discs. From this test the authors will obtain the time for a single motion to the large target.

With this information, they will be able to synthesize a time value for the test illustrated in Figure 19. The synthesized time will be in close agreement with the times recorded for the test illustrated in Figure 19, provided the same subjects are used in all tests. The results that may be obtained from tests carried out along the lines suggested will, I am certain, lead the authors to a different view on the dependence (or independence) of motions.

My third comment refers to the comparisons that the authors have made between their findings and the three predetermined time systems. In particular, I would comment upon their application of these systems. The authors state that they obtained their knowledge of the three systems from the brief descriptions contained in the *Industrial Engineering Handbook*. They did not contact Ralph Presgrave or me on any question relating to the application of BMT. They make no reference to our book, *Basic Motion Time-study*, and I can only assume that they did not read it. I cannot speak for certain about the extent of their contact with the principals of the other predetermined time systems referred to in their report but I am of the opinion that the substance of my remarks concerning BMT applies equally to the others.

To my mind the only disturbing aspect of their entire study is the fact that the authors have used BMT (and the other systems) to draw critical conclusions about these systems without making certain that they have correctly applied the time data. Time after time the principals of all predetermined time systems have stressed the need to have a thorough understanding of the application techniques before attempting to apply the time data. Through both the printed and the spoken word the user has virtually been guaranteed poor results if he attempts to apply the time data without instruction.

I do not know for certain that the authors have misapplied BMT. It is difficult to be certain from the report (complete though it is) exactly how all of the tests were performed and therefore to prepare an exact description of the motions used. From the text, however, I strongly suspect that the BMT analysis for the test that involves moving the brass pegs is incomplete. Viewed from this distance it seems likely that a separate motion would be required to insert the peg after it has been located at the entrance to the hole.

This question and others relating to BMT could have been resolved to a great extent by correspondence. If the problem of language can be overcome, I shall be more than pleased to work with the authors on any extension of their present researches and to provide all possible help in connection with the application of BMT.

Having been somewhat critical of the procedures followed by the authors (but I hope in a constructive sense) I should like to conclude by looking at one of the benefits that may come from studies of this nature. I refer to information relating to the allowance that needs to be made to net work time to overcome the effects of fatigue. No completely satisfactory scale of allowances of this nature has been developed as yet. In work measurement (whether it is done by stop watch study or by a predetermined time system) a blanket allowance to cover the effect of fatigue, based largely on experience and custom, is usually added to the net standard time. There is some evidence that the authors of this report have pursued a course of investigation that could lead toward the development of such a scale of allowances. For example, Figure 9 reproduces time data for moving back and forth in a horizontal plane at various angles from the body. At some angles the motions appear to be made comfortably, as reflected by the relatively low times. At other angles, the motions appear to be made with some difficulty, as reflected by the relatively high times. Perhaps these differences reflect the amount of extra time that needs to be allowed to overcome the effects of fatigue for motions performed under the difficult circumstances illustrated. If so, no doubt similar relationships for other types of motions and other circumstances could be found by an extension of these studies from which a full scale of fatigue allowances could be developed.

Comments on "An Experimental Evaluation of the Validity of Predetermined Elemental Time Systems"

by **CLIFFORD SELLIE**

President, Standards Engineering Company

THE MAY-JUNE, 1961 edition of *The Journal of Industrial Engineering* carried a very interesting although a very critical review labeled, "An Experimental Evaluation of the Validity of Predetermined Elemental Time Systems." The authors, Dr. Heinz Schmidtke and Dr. Fritz Stier of the Max-Planck-Institute for Work Physiology of Dortmund, Germany, are to be commended for some very interesting and worthwhile *experiments* they conducted in work measurement. They are not to be commended though, for their *evaluation*. Critical comparisons were made of three specific systems, MTM, WF, and BMT. But conclusions were drawn not only in regard to these specific predetermined time systems, but also in regard to the entire predetermined time field. Our firm, Standards Engineering Company, specializes in the use of the published predetermined time systems. We do not advocate any specific system, but select for our clients whichever of the predetermined time tables and techniques appear most appropriate for their needs. Accordingly, we believe it desirable not only to point out the errors Dr. Schmidtke and Dr. Stier made in regard to specific systems, but also the errors made in regard to the field of predetermined times.

On careful review of this article, I was distressed at two things: first, the lack of knowledge of predetermined times shown by the authors; second, the numerous cases of incorrect conclusions drawn regarding predetermined times. Perhaps we should not be too critical because adaquate information is not always readily available.

Before reviewing specific items, it appears pertinent to refer to an impartial article by two well known authorities in Industrial Engineering—Mr. F. W. Simerson, Staff Assistant to the Vice-President of Factories, Sears Roebuck and Company, and Mr. John E. Burns, Management Department, De Paul University. In their article on "Fundamentals of Predetermined Time Standards," Simerson and Burns write(1):

> P.T.S. systems are definitely not a new fad—nor a passing fancy. They are just a relatively new engineering tool—and a very powerful one IN EXPERIENCED HANDS. "EXPERIENCED HANDS" should be emphasized. A word of caution is called for here; individuals really should not express definite opinions to any extent on the subject before having applied P.T.S. for a sufficiently long period of time under the guidance of an experienced engineer. Much harm has been done in the past by so-called "experts" who, after reading a book or a series of articles on P.T.S., express either too enthusiastic or too deroga-

tory an opinion. Even more harm has been done by engineers attempting to apply P.T.S. systems without proper training. Usually, these men discredit this new tool in their own eyes and in the eyes of their Company.

Dr. Schmidtke and Dr. Stier in writing their article not only covered their experiments and predetermined times, but also presented some very fine abstract thoughts in regard to modern versus earlier psychology as a starting point for their criticisms of the predetermined times systems they knew about. Unfortunately the same points of psychology they used to flay predetermined times could also be used against them. They reviewed the emphasis that Gestalt psychology places on the fact that there is often a great deal more than meets the eye in many an item. This conclsuion is not only true but also has been abused again and again. It is quite obviously a true conclusion that what is obvious or shown or seen or observed may not be all the facets or characteristics of an item. That conclusion is correct. The conclusion that occasionally follows: "the whole is not equal to the sum of the parts," is only true by insertion of the phrase "if you do not know how to add and subtract for additonal parts."

SPECIFIC CRITICISMS

The authors should have been warned by their own selection of phrases from Gestalt psychology, even if they had not read Simerson and Burns. While criticizing very energetically the figures and conclusions of some of the predetermined time systems, they proceeded to make experiments and draw conclusions that were even more subject to error than the systems they criticized. Let us look at their article in detail.

Point 1—History of Predetermined Time Standards. The authors start out with the statement: "In the course of the last two decades a number of various predetermined elemental time systems have been developed, especially in the United States." If the authors were to give proper recognition to the development of predetermined times, they should have stated the correct time growth as "the last four decades." Predetermined times trace their origin back to the early nineteen twenties.

Point 2—Effect of Standards. In discussing the effects of standards under incentive conditions the authors state that while too low a demand is primarily of economic importance, an excessive demand over a long period of time may be injurious to health. This is a true statement that is irrelevant in regard to standards. Under proper incentive conditions, no matter where the standard is, the operator will not work to a point that will be excessive or injurious to the health.

Point 3—Forearm Motions versus Arm Motions. The authors drew their conclusion regarding the value of predetermined times based on three systems. The users of predetermined times generally recognize that they are mathematical tables. As such, these tables are groups of averages arranged in whatever format the developers of the system thought was most appropriate and useful. In arranging the tables into statistical averages the developers took into account the variables that they considered the most important. Of the fifty different predetermined time tables generally available, approximately two thirds of them are based upon rough groupings for practical everyday plant operations. On the other hand, there are predetermined time tables available which are developed with a great deal of accuracy. So, while the experimenters in this article may have felt justified in their criticism of some of the systems for not dividing arm motions into more basic arm categories, they should not have condemned all predetermined time systems. There are predetermined time tables available which do take into account the minor motion difficulties and the minor body elements on which they conducted their studies. While the research they conducted is probably one of the most scientific performed in recent years, the authors appear not to be familiar with the available predetermined time values. In fact, there are tables of greater preciseness available that would not only verify some of the ultra-detailed motions they studied but would have shown also that there were additional special motions that they overlooked.

For example, their studies indicated that motion times vary dependent on whether the whole arm or just the forearm is moved. Their studies also showed motion time is dependent on the direction of motions. The facts already available in some of the more detailed predetermined times show that motion times for forearm motions are less than motion times for arm motions. In addition, these detailed tables show not only that horizontal forearm motion takes different time than the vertical forearm motion, but that both of these times are different from the time for an oblique forearm motion. If this much detail is wanted, it is available, but it is seldom needed.

Point 4—Effect of Allowances. In the comparisons of the systems, again, both lack of facts and incorrect conclusions are shown. For example, the Methods-Time-Measurement tables are based upon day work or normal operations, whereas the Work-Factor tables are based upon incentive base. As a result, the two tables are from 15% to 25% apart, whereas the researchers assumed they were at identical levels.

Also, they missed the main purpose of predetermined times when they discuss the problem involved in adding an allowance (whether 20%, 30%, etc). The purpose of predetermined times is to provide consistent time values and not necessarily provide the same time values for each and every company. As a practical matter, different companies differ in the performance level they wish. Adding an allowance does not violate the purpose of predetermined times as long as you add a consistent allowance.

If the research group had gone into the purpose of predetermined time tables more thoroughly, they would

have recognized that adding a consistent percentage, or for that matter subtracting a consistent percentage, does not change the consistency of the time values, nor destroy the benefit of predetermined time tables.

Point 5—Different Systems Provide for Different Elements. Under the paragraph "Way-Time Relation of Target Motions as Dependent on the Size of the Target," criticism is made of the fact that the time values for the distance moved are not equal in the tables of the various systems. The authors had explained in prior paragraphs of the article that the different systems took into account different elements. The authors then should have realized that the time values could not and should not agree between the different tables (if the time values are of different elements).

Point 6—Effect of Precision. The authors studied the effect of the precision of a target motion on the following motion. The experiment was conducted on moving to a line, and then moving away. There are very few operations performed where the operator moves to a line, does nothing, moves away. Their conclusion is accepted, namely that there is an effect on following motions when extremely precise moves are made. However, the majority of the motions following precise assembly consists of equally precise insert or release motions. For these motions following precise assembly, the more detailed predetermined time tables provide additional time. However, I know of no table that provides for the type of experiment conducted, so the authors may be correct in their conclusions.

Point 7—Question Regarding Accuracy of Experimental Data. In their review of elemental times for move motions (which they have labeled "gripping distance") observed times show considerable fluctuations. This however has not stopped the research group from ignoring these unexplained variations from a smooth curve; and they have proceeded to draw a smooth curve from their studies as a basis for evaluating and criticizing the assembly times of the three selected predetermined time systems. The lack of correlation between the desired accuracy of the study and this curve fitting action is sure to raise some questions as to the reliability of the data. They specify "after extensive preliminary experiments," "the amount of data obtained during these experiments was great enough," "a training period of some time," etc. The lack of supporting data in the article makes it difficult for the reader to justify the conclusions. After all, one of the true criticisms that can be made regarding some of the developers of predetermined time systems is that same self-assurance of being right and not being able or willing to provide factual data to support that assured self-confidence. The lack of factual data regarding the extent of the experiments and their statistical reliability is made even more suspect by their conclusion: "no indirect influence may be imputed to the author, since the experiments were performed by an assistant." What are the facts, what are the statistics?

Point 8—Proper Use of Predetermined Time Standards Values. In their use of the predetermined time tables they have assumed that they understood and used the tables properly. However, they raised the question: "At first it might be presumed that we made some mistakes when selecting the individual elemental times." Then they put the question to bed by saying: "On studying the procedural rules of the three systems, however, it will be found that the elemental times selected by us are proper for consideration." How well we should be satisfied by this conclusion is evident by reviewing their analyses. For example, in their motion analyses for the Work-Factor tables the authors provide two Work-Factors, *SD*, for the operation—"move back for additional grasp." Unless there are conditions in the experiment that they have not revealed, the WF analyses would provide only one Work-Factor, *D*, for the "move back for additional grasp."

Point 9—Question Regarding Accuracy of Statistics Used. The authors conducted an experiment in which the operator performed a couple of motions, then left out a motion. The authors have drawn a conclusion from resulting difference in times—that predetermined time tables do not adequately provide for this subtraction. They determine by their subtraction on their own studies that the time should have been .063. By their studies of the single motion they determined that the time was .069. The conclusion is then drawn that this difference of about 10% proves that you cannot add and subtract for motions and times.

Let us consider how they arrived at this conclusion. They had two groups, one labeled "L" and one labeled "W." Group "L" took .059 for the operation for one piece; group "W" took .078. The authors averaged these figures out and concluded that .069 was the correct value. How could they use studies with a 32% variation (.059 to .078) to criticize a percentage difference of 9% (.063 to .069)?

Point 10—Effect of Frequency. In the research presented is a study of the effect of frequency on motion times. The studies show and the conclusion is reached that highly repetitive frequency does affect the motions and the times; that work performed in sequence does result in lower motion times. At this point they do specify that repetitive frequency "is not taken into account in any of the systems known to us." It is a question of practicality and need whether the three systems (MTM, WF, and BMT) should or should not provide for this specific problem. One of the earliest of the private predetermined time systems very carefully reviewed the problem of repetitive frequency.

After careful intensive studies under experimental conditions and actual factory operations, they found that apparent changes due to repetitive frequency were actually due mainly to operator learning cycle time and to the effect of short motions.

After observing some very erroneous conclusions by

research groups in America (who confused learning time requirements and allowances, with simultaneous motion time allowances, by use of inadequately trained research students), I believe additional detail is needed on the studies of repetitive frequency. Further study by Dr. Schmidtke and Dr. Stier should take into account:

1. The higher learning time required by longer cycle work.
2. The greater motion controls that may be required for complex work.
3. The shorter motions that may be used under very short cycle work.
4. The lesser motion controls required by short motions.

Point 11—Effect of Weight. In their evaluation of the effect of weight, they concluded that since their studies showed a difference of about 60% in motion time for comparable arm motions without weight, and with a weight of 1.5 kg. therefore the predetermined time tables available are wrong. Before agreeing with their conclusion, additional information is needed. Are their motion times with weights for the forearm only, or for the entire arm? Did the authors overlook the fact that the three systems they evaluated provide motion time values for average arm motions from arm to shoulder; and not for special conditions involving motions of forearm only? The authors would have found the effect of weight even greater if they had measured the motion times for hand motions with and without weight.

CONCLUSIONS

Let us now consider their final conclusions. After having reviewed their experiments, they say, "we are now able on the basis of our seven sets of experiments to criticize." Actually the question is not only are they in a position to criticize, but have they come up with some new contributions in the field.

1. They have verified the fact that three of the more widely known systems do not provide for special motion combinations and motions. They have not mentioned that there are predetermined time tables available that do provide for these exceptions.
2. They have not suggested that it is desirable to first determine what degree of accuracy you want, and then find tables that provide for your specific operations. This would have been a valid conclusion.
3. They criticize the adding of an allowance to establish the desired performance level. They fail to understand that performance goals may differ from company to company. When you are using a thermometer it does not make any difference whether you are using Centigrade or Fahrenheit. What you are interested in is getting consistent answers regarding temperature. That you might want to translate from one reference level to another does not ruin your tables.
4. In their conclusion that the direction of the motion affects the time they are correct. They are wrong in their conclusion that predetermined time tables are not available that provide for this difference in motions.
5. They have not pointed out that mathematical tables are averages. They apparently have not considered that it is possible that the combination of motions to be expected in a factory will offset so that it may be unnecessary to have predetermined time tables that provide for the detailed differences they evaluated. It has certainly been true in most United States plants that a table providing for an average of the different arm directions is more than satisfactory.
6. Their conclusion that the motion times for motion elements are dependent on the sequence of the motions is an accepted or recognized conclusion of most of the predetermined time tables.
7. Their conclusion that motion elements cannot be dropped out or subtracted was based on mathematics with a greater margin of error than the mathematics that they criticized.
8. The final conclusion is that wage payment "ought to be based on systems whose possible dispersion of errors remains within certain limits." This is a very logical statement, even though they use it to condemn predetermined times. However, do they know the margin of error in stop-watch performance rating? If they do, they might admit that the margin of error for performance leveling is usually considerably greater than the margin of error in most predetermined time tables. And if desired, predetermined tables with extreme accuracy and minimum margin of error are available.

SUMMARY

Dr. Schmidtke and Dr. Stier have conducted some very extensive experiments in motion times. Their contribution would have been greater if their knowledge of predetermined times and the purpose of predetermined times had been greater.

Predetermined times are here to stay. Predetermined times are not perfect, but they provide a needed technique for work measurement that is better than the other techniques available. Accordingly we may expect not only that predetermined times will continue to be used effectively, but that predetermined times will continue to be improved. We hope that the next research conducted will be positive, designed to improve predetermined times by finding and correcting errors.

REFERENCE

(1) Simerson, R. W., and Burns, J. E., "Fundamentals of Predetermined Time Standards," *Industrial Management*, February, 1959.

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A Quadratic Formulation of the Activity Location Problem[1]

by **ANDRE H. McHOSE**

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THERE is a common problem encountered in several engineering fields involving the need of assigning the location of some activity, plant, or military operation in relation to other fixed centers located over a given area. In general, for any activity location problem the variables can be classified as either 1. regional (such as labor costs and taxes) and/or 2. distance-based (such as transportation charges or electrical transmission line costs). This presentation is concerned with the distance-based aspect of activity location problems.

While the mathematical development will be presented in general terms, the application to several common problems will be apparent. As will be shown shortly, a mathematically optimum solution is derived for the second degree formulation of the activity location problem. In practical applications, a nonfeasible thought "optimum" solution is rejected for the nearest acceptable location solution. Let us consider the application in plant location studies.

The present approach in plant location, as shown in Yassen's work (8), usually embodies some form of factor weighting applied to a list of preselected sites, from among which the best is selected. The solution presented here, however, immediately singles out a local area for consideration based on distance related variables. The cost factors for both the regional and distance-based variables can simply be added to obtain the minimum cost solution. The choice of a plant, warehouse, or operation site involves other factors of course, for which costs and values are not readily assignable. These intangible and intuitive values may be applied according to the context of the problem.

One further point is made before giving the mathematical analysis. In the selection of a distance-based site, a linear function, represented by the sum of the products of the distance times cost-index, is usually employed. As it turns out, the usefulness and application of the second degree formulation lies in the fact that an explicit solution is derived which is a good approximation to the linear case (for which an explicit solution is lacking).

MATHEMATICAL FORMULATION OF THE PROBLEM

The problem considered in this article is described with reference to Figure 1 as follows: A finite number of fixed centers P_i are located over a plane area. Each fixed center has some relationship with variable activity center F to be located. Associated with the relationships between the variable center and each fixed center is some weighted index, V_i, representing a quantitative value bearing on the placement of the variable center. A location for the variable center F is sought, such that the sum of the product of some power of the distance D_i between the variable center and the fixed center times some power of the associated weights V_i equals a minimum. Let this relation be defined as the Z_m function, with the minimum value representing the optimum solution.

Expressed mathematically, in general form:

$$Z_m = \sum_{i=1}^{n} V_i^m D_i^m \qquad \text{Eq. 1.}$$

where

m = the degree of the equation.
n = finite integer, representing the number of fixed centers.

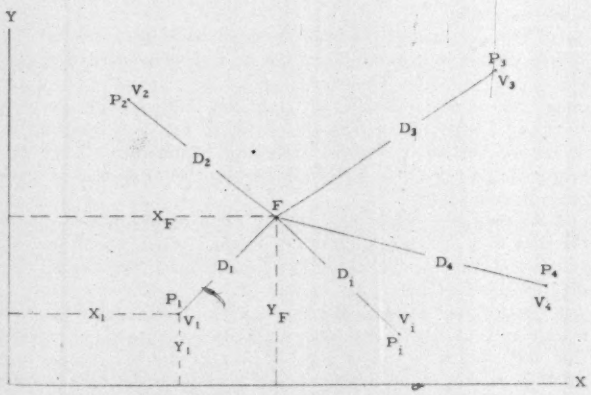

FIGURE 1. Diagram of Activity Location Problem.

[1] Based upon an MSIE thesis, The Pennsylvania State University, August 1959.

V_i = weighted factor associated with the relationship between the variable center and each fixed center.

D_i = distance between the location of the variable center (to be determined) and the fixed centers.

It has been shown by Miehle (7), that only an implicit solution for x and y coordinates of point F is obtained in differentiating the expanded form of the first degree expression. Trial procedures, therefore, must be employed in using the first degree (implicit) solution. Let us investigate the properties of the solution to the second degree[2] Z_2 function.

DERIVATION—SECOND DEGREE SOLUTION

The second degree Z_2 function is obtained by setting $m = 2$ in Eq. 1. Thus

$$Z_2 = \sum_{i=1}^{n} V_i^2 D_i^2 \qquad \text{Eq. 2.}$$

The expression for X_F and Y_F for two dimensions is derived as follows. Referring to the diagram shown in Figure 1, Z_2 can be expressed for the second degree Eq. 2. in the form:

$$Z_2 = \sum_{i=1}^{n} V_i^2[\sqrt{(X_F - X_i)^2 + (Y_F - Y_i)^2}]^2,$$

$$= \sum V_i^2[(X_F - X_i)^2 + (Y_F - Y_i)^2].$$

X and Y are independent variables, taking the partial derivative with respect to X

$$\frac{\partial Z_2}{\partial X} = \sum_{i=1}^{n} V_i^2 2(X_F - X_i),$$

for minimum, set equal to 0, then

$$2X_F \sum_{i=1}^{n} V_i^2 = 2\sum V_i^2 X_i.$$

Therefore

$$X_F = \frac{\sum_{i=1}^{n} V_i^2 X_i}{\sum_{i=1}^{n} V_i^2}, \qquad \text{Eq. 3.}$$

and similarly

$$Y_F = \frac{\sum_{i=1}^{n} V_i^2 Y_i}{\sum_{i=1}^{n} V_i^2}. \qquad \text{Eq. 4.}$$

ILLUSTRATION

For purposes of illustration a random set was formed, consisting of nine fixed centers, a through i, with variable center F to be located. The nine fixed centers were distributed over the area shown in Figure 2 by a random process, as were the nine associated weights V_a through V_i.

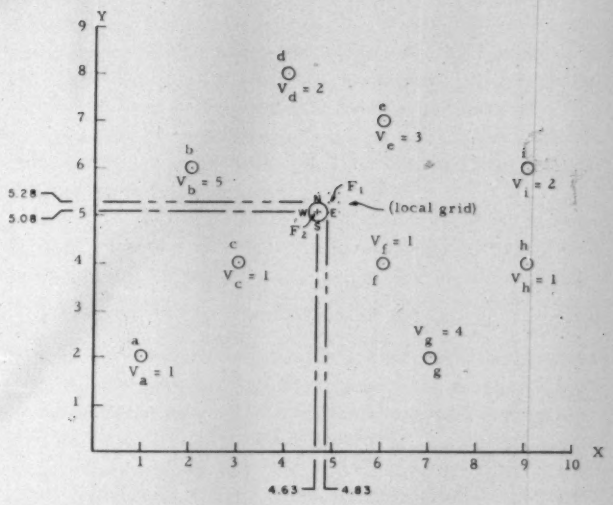

FIGURE 2. Activity Location Problem, Random Weights and Distribution.

In an actual problem the nine fixed centers might represent shipping and receiving points to and from the center F which is to be located. While the weights used in this illustration are treated as dimensionless numbers, in an actual application their value may represent transportation cost, frequency of use or any other appropriate index suited to the context of the particular problem. Let us consider the activity location problem diagramed in Figure 2.

The location of point F_2 for the problem diagramed in Figure 2 is determined by substituting the given values in Eq. 3. and Eq. 4. By this means, the numerical coordinate values are found to be $X_F = 4.629$ and $Y_F = 5.081$ units. The location F_2, shown in Figure 2, is the optimum location based upon the second degree Eq. 2. The optimum location of F_1 for the first degree equation can be found by an exploratory procedure, but before investigating the region of the minimum Z_1 value in detail, it is appropriate to determine the general nature of the Z_1 function for the area under consideration.

Computations for the Z_1 values for the problem diagramed in Figure 2 are shown in Table 1. The left hand column identifies the location at which the Z value is computed. The nine main columns a to i consist of two entries, the first being the distance between the variable center for which the Z value is to be determined and each associated fixed center; and the second entry being that distance times the weight for the given center. The last column, headed

$$Z_1 = \sum_{i=a}^{n} V_i D_i,$$

[2] Introduction to the opportunity, in some cases, of employing a second degree function for the linear form is gratefully credited to Dr. P. Frank Eiland, Staff Engineer, HRB-Singer, Inc.

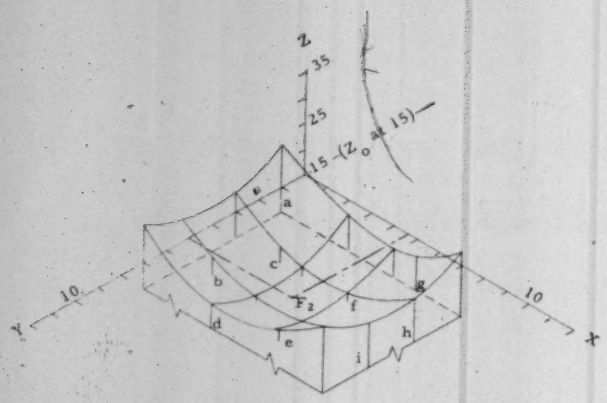

FIGURE 3. Topographical Map of Z_1 Function for Problem Diagramed in Figure 2.

consists of the indicated sum for the particular row. Points for the computed Z_1 values were chosen to facilitate the plotting of a topographical map of the Z_1 function. Study of the topographical map, Figure 3, shows the concave surface with a singular minimum characteristic to the Z function for one variable center.

A topographical map for the Z_2 function is not plotted, but it is understandable that a similar concave surface would result, with the exception that the gradient would be steeper because of the squared terms in the second degree equation. Knowledge of the Z function, as concave, is helpful in determining the minimum Z_1 value on an exploratory basis. A search for the minimum value was performed by plotting additional points 0.2 units apart at the local grid in Figure 2. The computation is not shown but it was performed in a similar fashion to Table 1. Using the location of F_2 previously determined as a starting point, exploratory Z values were determined in the general direction leading to decreasing values until a point was passed beyond which rising values indicated the minimum has been exceeded.

The minimum Z_1 value consistent with the accuracy of the graphical measurements obtained in this procedure is found to be at point F_1 shown in Figure 2. Thus the minimum Z_1 value as determined graphically is $Z_1 = 16.01$ units. Note also from Table 1 that the location F_2 from the second degree equation, yields a Z_1 value of 16.07 units. The difference therefore from the use of the F_2 solution for F_1 is found to be .37 percent for the data in this illustration.

By means of a similar procedure the Z_2 value, F_2 location, Z_1 value for point F_2, and (graphical) minimum Z_1 value have been determined for two other random weight distribution sets in the original studies. In each case the percentage difference of the F_2 solution for the F_1 solution was less than 1 percent. Recall that through derivation, F_2 is known to be an optimum solution to the second degree expression. As a result of the analysis of the randomized activity location problems, the conclusion can be drawn that the solution to the second degree Z_2 function is a good first approximation to the first degree Z_1 function.

Experimental observations along with those of the symmetrical case investigated in the original study lead to the following statement. In general, it can be stated that the "error" in using an F_2 location from the Z_2 function for the F_1 location for the Z_1 function decreases as both the location of the centers and the weight distribution occurs in a more symmetrical pattern.

In solving an activity location problem having both distance-based and regional type variables, algebraic addition of the Z values would be computed to yield the optimum solutions(s). In this case the general relation is in the form:

$$Z_t = \sum_{i=1}^{n} V_i^m D_i^m + \sum_{j=1}^{n} R_j \qquad \text{Eq. 5.}$$

where: the values for the new regional variable R_j have to be determined for each discrete location over the area under consideration.

As noted earlier, the order of the superposition yield-

TABLE 1

Computations for Z_1 Function for Problem Diagramed in Figure 2
(Distance measurements using 50-units to the inch scale)

F as variable center at	Associated Centers																		$Z_t = \sum_{i=1}^{n} V_i D_i$
	a		b		c		d		e		f		g		h		i		
	D_a	$_zV_a$	D_b	$_zV_b$	D_c	$_zV_c$	D_d	$_zV_d$	D_e	$_zV_e$	D_f	$_zV_f$	D_g	$_zD_g$	D_h	$_zV_h$	D_i	$_zV_i$	
a, (1, 2)	0	0	1.04	5.20	0.71	0.71	1.68	3.36	1.77	5.31	1.35	1.35	1.50	6.00	2.06	2.06	2.24	4.48	28.47
(4, 2)	0.75	0.75	1.12	5.60	0.56	0.56	1.50	3.00	1.35	6.75	0.71	0.71	0.75	3.00	1.35	1.35	1.60	3.20	24.92
(6, 2)	1.25	1.25	1.42	7.10	0.90	0.90	1.58	3.16	1.25	3.75	0.50	0.50	0.25	1.00	0.90	0.90	1.25	2.50	21.06
g, (7, 2)	1.50	1.50	1.60	8.00	1.12	1.12	1.68	3.36	1.28	3.84	0.55	0.55	0	0	0.71	0.71	1.12	2.24	21.32
(9, 2)	2.00	2.00	2.04	10.05	1.58	1.58	1.95	9.75	1.46	4.38	0.90	0.90	0.50	2.00	0.50	0.50	1.00	2.00	33.16
(1, 4)	0.50	0.50	0.56	2.80	0.50	0.50	1.25	2.50	1.46	4.38	1.25	1.25	1.58	6.32	2.00	2.00	2.06	4.12	24.37
c, (3, 4)	0.71	0.71	0.56	2.80	0	0	1.03	2.06	1.06	3.18	0.75	0.75	1.12	4.48	1.50	1.50	1.58	3.16	18.64
(4, 4)	0.90	0.90	0.71	3.55	0.25	0.25	1.00	2.00	0.90	2.70	0.50	0.50	0.90	3.60	1.25	1.25	1.35	2.70	17.45
f, (6, 4)	1.35	1.35	1.12	5.60	0.75	0.75	1.12	2.24	0.75	2.25	0	0	0.55	2.20	0.75	0.75	0.90	1.80	16.94
h, (9, 4)	2.06	2.06	1.82	9.10	1.50	1.50	1.60	3.20	1.06	3.18	0.75	0.75	0.71	2.84	0	0	0.50	1.00	23.63
b, (2, 6)	1.04	1.04	0	0	0.56	0.56	0.70	1.40	1.03	3.09	1.12	1.12	1.60	6.40	1.82	1.82	1.75	3.50	18.93
(4, 6)	1.25	1.25	0.50	2.50	0.56	0.56	0.50	1.00	0.56	1.68	0.71	0.71	1.25	5.00	1.35	1.35	1.25	2.50	16.55
(6, 6)	1.06	1.60	1.00	5.00	0.90	0.90	0.70	1.40	0.25	0.75	0.50	0.50	1.04	4.16	0.90	0.90	0.75	1.50	16.71
i, (9, 6)	2.24	2.24	1.75	8.75	1.58	1.58	1.35	2.70	0.80	2.40	0.90	0.90	1.12	4.48	0.50	0.50	0	0	23.55
e, (6, 7)	1.77	1.77	1.03	5.15	1.06	1.06	0.56	1.12	0	0	0.75	0.75	1.28	5.12	1.06	1.06	0.80	1.60	17.63
(1, 8)	1.50	1.50	0.56	2.80	1.12	1.12	0.75	1.50	1.27	3.81	1.60	1.60	2.12	8.48	2.24	2.24	2.06	4.12	27.17
d, (4, 8)	1.68	1.68	0.70	3.50	1.03	1.03	0	0	0.56	1.68	1.12	1.12	1.68	6.72	1.60	1.60	1.35	2.70	20.03
(9, 8)	2.50	2.50	1.82	9.10	1.80	1.80	1.25	2.50	0.79	2.37	1.25	1.25	1.58	6.32	1.00	1.00	0.50	1.00	27.84
F_2	1.19	1.19	0.69	3.40	0.48	0.48	0.75	1.50	0.59	1.77	0.44	0.44	0.97	3.88	1.12	1.12	1.12	2.24	16.07

ing the composite Z value should be dependent upon the predominating effect of either variable. If the effect of the regional variable is small in comparison to the distance-based variable, then algebraic addition within the region of a minimal contour should be performed. For large regional differences, a programmed search over the whole territory under consideration is indicated.

A PROCEDURE FOR LOCATING SEVERAL VARIABLE CENTERS

The derivation and illustration in this presentation apply to activity location problems with an unlimited number of fixed centers and one variable center to be located. It is possible to obtain a first approximation to the location of several variable centers by an iterative application of the method illustrated for the location of one variable center. An actual example is not given here but the method of solution is apparent. Essentially one variable center is first located with respect to the fixed centers and then each succeeding variable center is located with respect to the fixed and the previously located variable centers. While the first program is suboptimal, the method does yield a quick way of obtaining an approximate solution which can be refined by charting the Z function in the region of the solution.

A significant property of activity location problems having a large number of variable centers is the prospect of possessing either one or several optimal solutions. Elaboration on this is not within the scope of the present study, but a knowledge of the multisolution property aids in gaining an understanding of the more complex class of problems. It is apparent that some other approach, perhaps a programmed computer search is indicated for activity location problems possessing a large number of variable centers.

DISCUSSION

As a very practical matter, since a solution to an activity location problem is based upon historical or present economic data, it should be evident that each solution has an implied useful life. In fact, the continuing economic, technical, and natural changes help create the incentive to relocate activities to a more advantageous site.

There are several other aspects of the problem that bear consideration, including the price system and the effect of a competitive market. Koopmans and Beckmann (5) have presented a searching investigation on the assignment problem in which rent, transportation cost, and the price system are considered in a competitive market. They comment on ". . . the difficulty of establishing meaningful relations between location rents and transportation costs in a problem as elementary, in comparison with the actual complexities of locational markets, as the quadratic locational assignment problem."

In his comprehensive study on location theory, Greenhut (2) considers both the demand and cost factors in determining the economic location of a plant. A significant aspect of the problem, pointed out by Greenhut is the fact that a least cost site is desired at a particular output. Where production output can be assumed to be independent of location, then this is not a relevant consideration, but operations can be visualized where these differences must be considered.

Much of the past work on activity location is concerned with the economics of regional, national, and international development. The works of Hoover (3), and Isard (4) relate to this more general economic context.

It is very likely that future activity location studies of sufficient importance and complexity will be investigated by means of computer programming as indicated earlier. Baumal and Wolfe (1) have published a solution to the warehouse location problem employing linear programming. This study, however, represents a special case since the problem treated is that of selecting (and allocating shipments to) public warehouses from among those already existing (located). For a penetrating analysis, employing a linear and nonlinear programming formulation of the problem, the work of Lefeber (6) is cited.

SUMMARY

In summary, choice of the function and methodology employed in an activity location study rests with the analyst familiar with the context of the problem. The particular value of the solution given in this article lies in the fact that it is explicit and optimal for the second degree formulation of the problem. For the linear case, as has been demonstrated, values obtained from Eq. 3. and Eq. 4. closely approach the common linear solution. This substitution of a quadratic expression for a linear relation thus serves as a useful analytic device for handling distance-based variables in activity location studies.

REFERENCES

(1) Baumal, William J., and Wolfe, Philip, "A Warehouse Location Problem," *The Journal of the Operations Research Society of America*, Vol. 6, No. 2, March-April, 1958, pp. 252–263.

(2) Greenhut, Melvin L., *Plant Location in Theory and in Practice*, The University of North Carolina Press, Chapel Hill, 1956, pp. 334.

(3) Hoover, Edgar M., *The Location of Economic Activity*, McGraw-Hill Book Company, New York, 1948.

(4) Isard, Walter, *Location and Space-Economy*, Technological Press of Massachusetts Institute of Technology and John Wiley and Sons, Inc., New York, 1956.

(5) Koopmans, Tjalling C., and Beckmann, Martin, "Assignment Problems and the Locations of Economic Activities," *Econometrica* 25, January 1957, pp. 53–76.

(6) Lefeber, Louis, *Allocation in Space*, North-Holland Publishing Company, Amsterdam, 1958, pp. 151.

(7) Miehle, William, "Link-Length Minimization in Networks," *The Journal of the Operations Research Society of America*, Vol. 6, No. 2, March-April, 1958, pp. 232-243.

(8) Yassen, Leonard C., *Plant Location*, American Research Council, New York, 1958, pp. 220.

Industrial Engineering's Role in Planning for and Setting Up a Tape Controlled Facility[1]

by **LEROY F. HERDA**

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WHEN the management of the Kearney and Trecker Corporation decided that Milwaukee-Matic II machines would be used for production, the Industrial Engineering Department was given the assignment of setting up the operating department and providing the services necessary to operate the machine. It was felt that the duties and responsibilities would fall into two categories: one was the duties and responsibilities that would always remain a function of the Industrial Engineering Department, the other would be those functions that would be eventually turned over to the manufacturing group. In determining how responsibilities should be allocated, we did not limit our thinking to Milwaukee-Matics because we could visualize other tape controlled machines such as lathes, grinders, and drill presses being used in the future.

RESPONSIBILITIES

As stated above, Industrial Engineering was given the responsibility of setting up the operating department as well as performing what would be considered normal Industrial Engineering functions as a service to a tape control department. It was felt that the following factors would have to be considered.

1. Location of the machine and department layout.
2. Tool crib facilities.
3. Tool standardization.
4. Shop personnel.
5. Programming.
6. Tapes—preparation and storage.
7. Tool design.
8. Loading and scheduling within the department.

After the department was operating effectively, it was felt that the Industrial Engineering Department would be responsible only for maintaining tool standardization, programming, tape preparation and tool design.

During the time the department is under Industrial Engineering, the only responsibility of the shop will be service to and maintenance of the machine.

When the machine is turned over to the shop, the shop responsibilities will be:

1. Operate the machine.
2. Tool setting.
3. Maintain tool crib.
4. Control tape storage.
5. Maintain the machine.
6. Loading and scheduling within the department.

PLANNING OF FACILITIES

The only machine available to us was the Kearney and Trecker Milwaukee-Matic II. This machine is capable of drilling, boring, reaming, tapping, milling, grooving and other related machining. The machine is completely tape controlled except for loading and unloading the workpieces on the pallets. The tape controls shuttling of the pallets, movements of the head in three planes, indexing of the table and changing tools up to 2⅝″ in diameter and 7½″ long. The machine was available with an eight-position index table or an infinite index rotary table. An eight-position index machine was chosen because only a limited number of parts made at Kearney and Trecker require more than an eight-position index (Figure 1).

The department was to start with one machine; the second machine was to be available about nine months later. When the number III size machine became available, one machine of that size was also to be added.

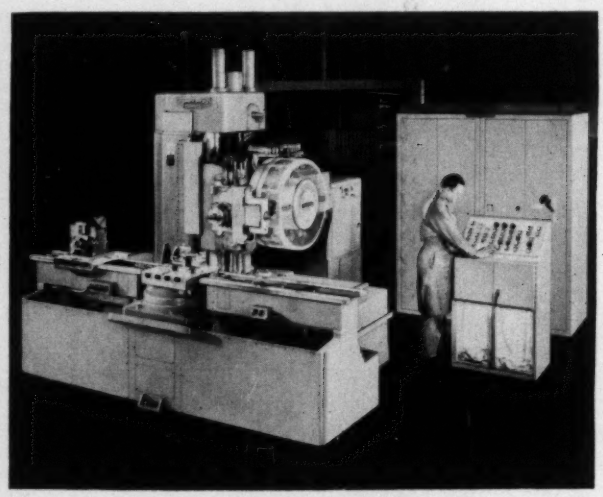

FIGURE. 1. Kearney and Trecker Milwaukee-Matic II.

[1] An entry in the Professional Paper Contest sponsored by the Milwaukee Chapter, American Institute of Industrial Engineers.

INSTITUTE INTERESTS

Individuals, chapter officers, institute officers and others are invited to become primary reporters and send in interesting highlights on local, national and international events. The principal criterion is that the item be current and of general interest. Since publication space represents an investment of your funds, please help us avoid "wordy stories." Material can best be handled if it is typed and double-spaced. Pictures to accompany these notices—or just good pictures with explanatory notes are welcomed. Send the material to Professor Wilson J. Bentley, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma. If you forget this address, send it to the JOURNAL *office in Atlanta, and I will get it.*—EDITOR.

FELLOW OF AIIE

Herbert Hoover, the thirty-first President of the United States was born in West Branch, Iowa, on August 10, 1874. Orphaned at eight, he was brought up by relatives. Young Hoover was forced to leave school at the age of fifteen in order to help support himself and had nearly given up hope of continuing his education when he read of the opening of Stanford University. Hoover left his job, and with a few hundred dollars, set out to earn his way through college. Hoover chose the Mining Engineering curriculum at Stanford because of his interest in mathematics and graduated in 1893 at the age of nineteen.

His first "position"—the only job he could find—was pushing a mine car on the lower levels of a Nevada silver mine. However, he soon lost his job when the mine closed down. As he put it, he "learned what the bottom levels of real human despair are paved with, that is, the ceaseless tramping and ceaseless refusal at the employment office every day."

Finally Hoover got a job with Louis Janin, an outstanding mining engineer, and was sent to New Mexico as an assistant mine manager. Because of his excellent work in coordinating the work of the staff and the miners, Hoover was soon called back to Mr. Janin's personal staff.

In 1897, Hoover was offered a job by a British mining firm operating in Australia. He accepted and soon became the manager of a gold mine. Because of his skill in examining mining prospects and planning plant layouts, he was dubbed by his friends "The Chief", a nickname by which he is still known.

Hoover's growing fame lead to the offer of a job at China's Bureau of Mines. At the same time he sent his acceptance to the Chinese government, he cabled Miss Lou Henry, who had been a fellow geology student at Stanford, proposing that they be married.

Miss Henry accepted and in March, 1899, the Hoovers sailed for China. In his work there, Hoover made a number of long geological exploration trips over China and into Mongolia. In 1900, the Hoovers were under seige in Tietsin, China, for nearly two months during the Boxer Rebellion. The Chinese government fell as a result.

But, as the Hoovers prepared to sail for America, Hoover was offered a position as general manager of a British-owned coal mine. A year later he joined the British firm, Bewick,, Moreing and Company, as a junior partner.

During the next few years Hoover circled the globe several times in looking after the firm's wide holdings. In 1903, the Hoover's first child was born in England—and was taken to Australia when he was five weeks old. The Hoover's second son was born in London in 1907.

Then in 1908, Hoover left the British company to form his own mining engineering company and spent the next six years doing free-lance engineering all over the world.

The Hoover family was in England when the first World War began. Almost immediately Hoover gave up what would probably have been a considerable fortune in producing metals and became Chairman of the Commission for Relief in Belgium. This organization was credited with saving thousands in Belgium and Northern France from starvation. Hoover continued to direct the CRB until 1919, and upon its dissolution, was made an honorary citizen of Belgium.

Hoover was appointed Administrator of the United States Food Administration by President Wilson in 1917. Hoover supervised the production and distribution of foodstuffs for the war effort. After the Armistice, Hoover continued with the Food Adminis-

HERBERT HOOVER

tration, providing food, medicine, and clothing for thirty-two nations. In 1918, Hoover was appointed Director of the Relief and Rehabilitation of Europe by President Wilson, Prime Ministers Lloyd George and Clemenceau and Premier Orlando. Hoover's new duties included not only staving off hunger and disease but also the economic storing up of weak governments to withstand the growing threat of Communism. To facilitate his job, the "Big Four" put Hoover in charge of coal mining and all rail and water transportation in Europe. As a member of President Wilson's Committee of Economic Advisors, Hoover assisted in the preparation of the Versailles Peace Treaty.

In 1920, Herbert Hoover was elected president of the American Institute of Mining and Metallurgical Engineers.

In 1921, Hoover organized the European Relief Council which raised thirty million dollars to aid starving children in Europe. In the same year he took charge of the relief program to alleviate the effects of a famine in Russia. Sixty-two million dollars worth of food and supplies were sent to Russia under his direction.

Hoover's political career began in 1920 when support developed in both major political parties for his nomination for President. He was nominated at the Republican Convention in 1920 and received thirteen votes.

Warren G. Harding, the Republican nominee and President-elect asked Hoover to join his Cabinet as Secretary of Commerce. Hoover accepted and as his first project, worked to hasten the end of the 1921-22 depression. Hoover concluded that recovery depended on increased productivity. He concentrated on the elimination of waste and on standardization of goods in industry, improved transportation, expansion of electrical power service, conservation of resources and pure and applied research.

After Harding died in 1923, Hoover continued his work under Calvin Coolidge. Hoover promoted new housing, child labor legislation, shorter working hours, labor-management negotiation, commercial radio broadcasting and aviation.

After Coolidge chose not to run for re-election in 1928, Hoover was nominated on the first ballot for President of the United States. Opposing Alfred E. Smith in the subsequent election, Hoover swept all but eight states and carried the House and Senate to Republican majorities.

Only eight months after his inauguration the Great Depression of 1929 began. Hoover sped up his public works program to combat unemployment. The Hoover Dam was begun in 1929, a number of the Tennessee Valley dams were begun and plans were completed during his administration for the Grand Coulee Dam. President Hoover proposed a one-year moratorium on international payments which was accepted and later credited with saving the German government. Hoover proposed measures to relieve mortgage foreclosings and directed Federal agencies to support farm prices. He led in establishing the Reconstruction Finance Corporation.

President Hoover accepted the Republican nomination for a second term in 1932, but he could spare little time for campaigning from his fight against the Depression. He made only nine major speeches.

Franklin D. Roosevelt carried 42 states in the 1932 election and Herbert Hoover, after nineteen years of public service, retired to his home in California.

In 1935, Mr. Hoover came out of retirement to oppose many of the activities of the "New Deal" and to warn the United States of the menace of Communism.

In 1936, Hoover became Chairman of the Boys Clubs of America. In 1939, he was appointed Chairman of the Commission for Polish Relief. In 1940, he organized the Committee on Food for the Small Democracies and again became the chairman of the Belgian Relief Fund.

At the end of World War II, President Truman asked Hoover to serve as coordinator of Food Supply for World Famine, an organization operating in 42 countries. Jointly with others, Hoover established the United Nations International Children's Emergency Fund and CARE.

In 1947, President Truman appointed Mr. Hoover Chairman of the Commission on Organization of the Executive Branch of the Government. About 75% of the Commission's recommendations have since been adopted. The Commission, with Hoover again as Chairman, was re-established in 1953 by President Eisenhower and about the same proportion of recommendations was accepted from it. It has been estimated that the work of these two Commissions has saved the American taxpayers over ten billion dollars.

In 1954 the rank of Fellow of AIIE was conferred upon Mr. Hoover.

In 1958, he represented the President on United States Day at the Brussels World's Fair where he received the acclaim due him as the man who had helped save so many lives in Belgium and France through two wars. At the Republican National Convention in 1960, Hoover was honored as the grand old man of the Grand Old Party.

Today, nearly 87 years old, Mr. Hoover continues vigorously speaking and writing on the subject he holds most dear—the preservation of freedom.

Recently, he has accepted an invitation to serve as Honorary Chairman of the dedication ceremonies of the new 20 story United Engineering Center. The dedication ceremony will take place in late October.

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AIIE GENERAL NEWS

ENGINEERING ENROLLMENTS AND PROJECTED DEGREES*

In the last issue of *Newsletter,* a short article announced that freshman engineering enrollments had dropped for the third year while total college enrollment continued upward. What follows is a further analysis of the implications of such continued deterioration in the relative position of engineers.

From 1950 to 1957, freshman engineering enrollment rose at a marked rate. In 1958, however (due to many factors including a recessionary trend and the popularity of careers in science), engineering freshman enrollments suddenly dropped 11%.

How do freshman enrollments in engineering affect degrees granted? During the last few years, rates of retention have not fluctuated to a great extent (48.7% for engineers entering in 1956 and graduating in 1960). By 1964 the graduating class should be in the neighborhood of 34,000. In order to achieve our present level of degrees (37,800) in 1965, freshman enrollments this fall (1961) must increase by over 8,000 (or 12%).

Masters' degrees as a percentage of bachelors' degrees one year earlier have dropped from 20.2% in 1956 to 18.3% in 1960, although the actual number increased from 4,589 to 6,989. Doctors' degrees compared with bachelors' degrees three years earlier remained at 2.5% during the same interval.

ENGINEER ATTITUDES

In a recent survey titled, "A New Look at Engineer Attitudes," less than 60% of the engineers questioned felt the flow of technical information was sufficient. The study concludes that technical men are still discontented with their lot in industry. More than one-quarter of the respondents were not satisfied with current jobs. Though there is a natural reluctance to make job changes, 80% felt that changing jobs brought better professional opportunities and better salaries. Inadequate recognition for contributions to

* Excerpts from Engineering and Scientific Manpower *Newsletter* #130, July, 1961.

the company were among the strongest reactions from engineers. Copies of the report are available from Industrial Relations News, 230 West 41st Street, New York 36, New York, at a cost of $3.50.

UNIVERSITY SCIENTISTS AND ENGINEERS

Forty-four percent of the total 70,000 scientists and engineers at United States colleges and universities were engaged in research and development during 1958 according to a National Science Foundation report. Expeditures for Research and Development in the natural and social sciences increased from $410 million in 1954 to $736 million in 1958. To match the obvious increase in manpower requirements, universities have apparently allocated more faculty time rather than increase the number of faculty engaged in Research and Development. The number of persons involved rose by only 3% during the same period of time (*Reviews of Data on Research and Development, #27, NSF*).

TECHNOLOGICAL PERSONNEL IN INDUSTRY

According to the National Science Foundation (*Scientific and Technical Personnel in American Industry—Report on a 1959 Survey, NSF 60-62*), American industry employed 800,000 engineers and scientists as of January 1959. Now the number is nearer 870,000. The survey on which this estimate was based missed only the very small organizations and self-employed professionals. The actual count was 764,000, distributed as follows: engineers, 615,000; chemists, 72,000; biologists, 18,000; earth scientists, 15,000; physicists, 15,000. The remaining 29,000 were either in smaller groups or unclassified. During the calendar year 1958 the number of industrially employed engineers and scientists increased by 5%.

The authors of the report point out that the annual rate of engineering and scientific manpower increase has declined—from 13% in 1954 to 5% in 1958. Perhaps this fact calls for some reconciliation from another significant statistic—namely, that funds for research and development have risen 10% per year during the same period. We may grant that equipment costs more than manpower, but an effort should be made to determine whether monetary support for research and development is outstripping the kind of manpower needed to handle Research and Development efficaciously.

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REPORT BY DELEGATION TO U.S.S.R.

Recent achievements and future goals of the Soviet Union in the field of engineering and engineering education and manpower utilization are presented in a report published by Engineers Joint Council, Inc. For instance, the USSR annually graduates approximately 117,000 engineers, compared to 38,000 for the United States, and Soviet plans call for substantial increases in that number.

The report, entitled "The Training, Placement and Utilization of Engineers and Technicians in the Soviet Union," is based on a tour of the Soviet Union made last year by six representatives of United States engineers sponsored by Engineers Joint Council with financial support of the National Science Foundation and under an exchange agreement between the U.S. and the U.S.S.R. The 112 page printed document is available in limited numbers for $1.00 from Engineers Joint Council, 29 West Thirty-Ninth Street, New York 18, New York.

The six sections of the report cover 1. Engineering and Technicum education in the U.S.S.R.; 2. Planning of Manpower Requirements and Placement of Graduates; 3. Continuing Education of Engineers and Technicians Employed in Soviet Industry; 4. Motivation in Education; 5. Industrial Research, and; 6. Utilization of Engineers and Technicians. Each section was written by a member of the delegation whose professional background qualified him to evaluate specific aspects of Soviet engineering.

Throughout the report there are indications of the impressions made upon the delegation by the serious determination and zeal with which the people of the U.S.S.R. approach technical education. It was pointed out that Soviet secondary education prepares highly qualified students for advanced education, and that the Soviet "freshman" is generally better prepared for an engineering education than his American counterpart.

The education section, written by H. Russell Beatty, President of Wentworth Institute in Boston, describes the high degree of specialization required of engineers and technicians, and defines the different types of engineering and engineering related institutions. The Soviet engineering institutes are comparable to engineering colleges in the United States. The Soviet technicum is a counterpart of the American technical institute or technical junior college. A high degree of practical industrial experience is integrated into the study program of both institute and technicum students.

Dr. Oleg Hoeffding, an economist with the Rand Corporation, and a specialist on Russian economic affairs, gives a penetrating description of the framework of the master operating plan under which the training, distribution, and utilization of Soviet engineers and technicians take place. If institutions within a given republic are inadequate to prepare its needed technical personnel, the Soviet Ministry of Higher Education will make necessary adjustments to send professors and students to more highly developed areas for further education and training.

The enthusiasm with which technically employed persons in the U.S.S.R. approach evening and correspondence study is discussed by Dr. Sidney B. Ingram, who spent many years as director of education and training for Bell Telephone Laboratories. His observations include the strong incentives offered by government and industry for employees to improve their professional skills by undergoing part-time study, and the large numbers of persons engaged in this form of education.

Carlton S. Dargusch, an attorney and former deputy director of United States Selective Service, gives revealing observations on the motivation underlying the strong educational desires of the Russians. Some of the motivating forces are a strong sense of patriotism, the preferential financial compensation, the better standard of living for the technically educated which includes better housing, and the possibility of obtaining luxuries such as an automobile or a *Dacha* (summer cottage), the higher social prestige which exceeds that held by Americans of like status, as well as virtual exemption from military service.

The "Socialist Agreement on Cooperation", providing that professors shall work with enterprises with no additional pay, and also providing for use of engineering institute research facilities by plant research men and plant facilities by professors, is included in the observations on Research by Walter E. Lobo, a consulting chemical engineer. He also pointed out that the Soviets emphasize copying and adapting the best designs of Western Europe and the United States, but that occasionally improvements are made which they say would astonish the original designers.

Soviet practices on utilization are covered by comments made by Robert M. Mahoney, an engineer currently engaged in personnel policy development for Union Carbide Corporation. He concluded that from the point of view of United States practice Soviet engineers and technicians are not utilized to the fullest degree based on their highly specialized education. As an example, a railroad engineer may for a time actually drive a locomotive. He also related, however, the Soviet reasoning for the belief that their practice is sound. Mahoney also suggested that women engineers are not utilized to the degree that the Russians have implied they are, but nevertheless remain a vital part of the professional manpower pool.

A brief concluding section outlines the delegation's views of the implications for the United States presented by the Soviet emphasis on engineering and engineering education. One of these is the impact on our foreign relations made by the Soviet readiness to deploy engineers and technicians in underdeveloped countries.

RESEARCH ACTIVITIES

HAROLD E. SMALLEY

Dr. Harold E. Smalley of Georgia Institute of Technology has received a grant of $53,992 to continue his research in the development of a decision theory for hospital and medical administration. This Public Health Service grant was approved on July 25, 1961, by the Surgeon General in Washington on behalf of the Division of General Medical Sciences of the National Institutes of Health to support this ongoing research project during 1962.

Cost prediction models and decision procedures for supply items used in patient care will be subjected to field tests in hospitals across the nation. The objective of this research program is the development of procedures for making rational hospital supply decisions, with regard to both economic and human considerations. The general approach involves the use of Industrial Engineering principles and practices in hospital management.

The project is being conducted through the Engineering Experiment Station in cooperation with the School of Industrial Engineering at Georgia Tech, Emory University, major hospitals in the Atlanta area, and the Georgia Hospital Association. Other professional staff members on the project are Dr. John T. Doby and Dr. Jerry L. L. Miller of Emory's Sociology Department; Miss Louelia Owen and Miss Pamela Hendrix of the Nursing Division of Emory University Hospital; Dr. A. D. J. Emerzian, on leave from the University of Connecticut; and Mr. Howard W. Woods, Jr.

PERSONALITIES

E. ROBERT ASHWORTH

Bob Ashworth, formerly Assistant Professor of Industrial Management, Auburn University, has been appointed as the Director of the Computer Center and Associate Professor of Mechanical Engineering, Tuskegee Institute. The new 1620 IBM computer will be located in the School of Engineering. He is a graduate of Purdue University, BSME 1950, MS in Statistics in 1957 and has done further graduate work at Oklahoma State University. He is a Registered Professional Engineer in Alabama.

JOSEPH D. CARRABINO

Los Angeles' new mayor, Samuel Yorty, recently appointed Professor Joseph Carrabino of U.C.L.A. to the Los Angeles Board of Harbor Commissioners. At the first meeting of this group, Professor Carrabino was selected to be Chairman of this Board. Professor Carrabino is an active member of the Los Angeles Chapter of AIIE, serving on the program committee this year. He announced at a news conference that he hopes to apply industrial engineering techniques to the harbor operations.

MERRILL M. FLOOD

Merrill M. Flood, Professor of Industrial Engineering, The University of Michigan, has been appointed the Director of Professional Relations of AIIE. Dr. Flood is also Professor of Mathematical Biology, Department of Psychiatry and Senior Research Mathematician at the Mental Health Research Institute. He received the doctoral degree from Princeton University and has had varied experience in science and research. He holds membership in a number of professional and honorary organizations. He is married and has six children.

JACK R. WALKER

JACK R. WALKER

In the fall of 1961 Jack R. Walker, Associate Editor of the *Journal of Industrial Engineering*, begins a course of study at Oklahoma State University, Stillwater, Oklahoma.

For the past five years Jack has been on the faculty at the Georgia Institute of Technology serving in the past twelve months as assistant professor in the School of Industrial Engineering. A native of Meridian, Mississippi, he was graduated from Mississippi State University with a degree in mechanical engineering and from Georgia Tech with a master of science degree in Industrial Engineering. While at Oklahoma State University he will pursue a course of study in Industrial Engineering leading to the doctoral degree.

Before becoming an associate editor, Jack served as business manager of the *Journal*. He has been a director in the Atlanta Chapter of AIIE and is a member of Alpha Pi Mu.

SENIOR CHAPTER NEWS

WINSTON-SALEM CHAPTER

The 11th Annual Industrial Engineering and Advanced Management Conference, co-sponsored by the Winston-Salem chapter, AIIE, and the Greensboro chapter, SAM, was held in Winston-Salem on March 23-24, 1961 at the Robert E. Lee Hotel. Technical topics included:

"The Use of Photography in Industrial Engineering" by Kenneth T. Lassiter, Technical Editor, Sales Service Division, Eastman Kodak Company, Rochester, New York.

"Management Incentives for Control of Indirect Cost" by Robert J. Levin, Manufacturing Vice-President, United Mills, Vice-President, Unified Consultants, Mt. Gilead, North Carolina.

"Master Standard Data" by Serge A. Birn Company, Louisville, New York. "Industrial Engineering in Arbitration" by Peter Seitz, Labor Management Consultant, New York, New York.

The conference activities were climaxed by a banquet with Mr. Jerome Barnum as guest speaker. His topic was "Humanics of Industrial Engineering."

ROCHESTER CHAPTER

More than 190 Region V Industrial Engineers attended their Spring Conference on Friday and Saturday, April 21 and 22, under the sponsorship of the Rochester, New York Chapter.

The primary theme of Friday's sessions was the part management must play in effective management controls. The conference was opened with the topic "The Development of Management Controls"; discussed by Mr. Arthur J. Hatch, Vice President and General Manager of the Commercial Products Division of Stromberg Carlson Company. Mr. Robert S. Rice, Managing Editor of *Factory*, rounded out the morning program by presenting his survey findings on whether incentives are a "Panacea" or a "Pain." After lunch the subject changed to "The Company's Goals and the Industrial Engineer's Part in Achieving Them." Mr. Richard M. Wilson, Manager of Film Manufacturing at the Kodak Park Works of Eastman Kodak Company tackled this

problem followed by Mr. Wallace E. Wilson, General Manager of the Rochester Products Division of General Motors, who discussed the "Evaluation of Results of Production Planning and Control."

Saturday's program was technically oriented for the Industrial Engineer. Mr. Clinton B. Hutto, Comptroller of Haloid-Xerox, Inc., kicked off with a dissertation on "Industrial Engineering and Cost Accounting Teamwork for Lower Costs." He was followed by Mr. Donald D. Thompson, Senior Engineer for Ernst and Ernst Company who presented some "Tools for Controlling Indirect and Expense Costs." Saturday's luncheon speaker was Mr. Robert E. Allen, former National AIIE President, who is now Vice President of Operations for Shuron Optical Company, Division of Textron, Inc. Mr. Allen elaborated on methods of "Measuring Industrial Enginering Performance." After lunch the conferees became enlightened in the field of "Human Physiology and Worker Productivity" by Mr. Lucien A. Brouha, Manager of Fatigue Research for Haskell Laboratories of E. I. duPont de-Nemours, Inc. The conference was brought to a triumphant close with a slide talk on PACE (Performance and Cost Evaluation) by Mr. Carl M. Boswell, Supervisor of the PACE Service Section of Northrup Corporation.

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PROFESSIONAL RELATIONS

By MERRILL M. FLOOD, *Director*

Professional Relations is guided by five principles:

1. Establish close working relationships with carefully selected engineering and management societies as well as government agencies.

2. Develop criteria for all Institute members to follow in maintaining these effective relationships.

3. Promote joint sponsorship of activities such as meetings, seminars and conferences at local, regional and national levels.

4. Encourage the bringing together of all engineering societies to a unified concept of "Engineering."

5. Intensify Institute efforts to raise professional standards and enhance the Industrial Engineering profession in the eyes of other professions.

To help achieve these goals, some of the top people of AIIE have accepted key jobs in Professional Relations.

1. O. J. Feorene, Engineers Joint Council Director: AIIE is an important member of EJC and takes a very active role in participating in the many committee and taskforce studies undertaken by EJC. To name only two, we have contributed to the change in the EJC Constitution and By-Laws and provided guidance in developing and publishing the *Engineer*.

2. J. A. Richardson, International Relations Director: International Relations have been substantially strengthened in recent years. One fine association with our good neighbor to the north—Canada, is a very noteworthy example. Inquiries are being received from all over the world asking how chapters might be established in foreign countries. This increased interest has necessitated the formation of a taskforce to study the problems and submit a recommendation to the Board in December 1961. Also, under the direction of Mrs. Gilbreth, Alex Rathe and Nick Radell, a special conference is being planned in conjunction with the CIOS conference scheduled in New York in September 1963.

3. J. R. Shelton, Inter Society Affairs Director: Effective working relationships are maintained on a continuing basis with all recognized professional societies in the field of engineering and science. Offers to become members of new and existing societies are constantly being appraised.

4. M. R. Lohmann, Engineers Council for Professional Development Director: Excellent relationships have been maintained with ECPD. Once we have met the total full member requirements we will apply for membership in this organization.

COMMUNITY SERVICES AND THE INDUSTRIAL ENGINEER

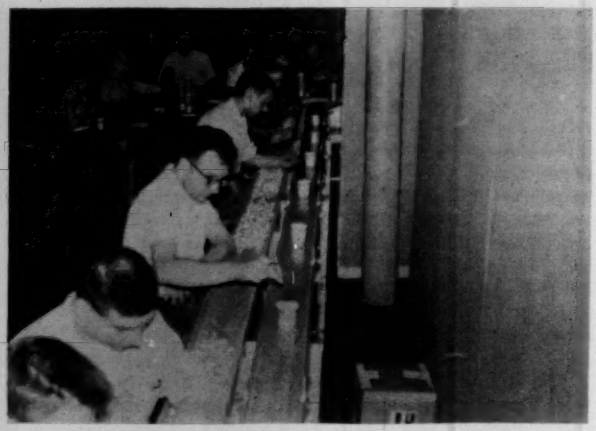
By GLENN D. WOLFE, *Region VIII Community Services Chairman*

When we as members of a professional society define our activities in this manner—"Industrial engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skill in the mathematical, physical and *social sciences*. . . ."—it often occurs to me that we could do much to improve our activity along the lines of practical, applied social and psychological sciences. This thought stems from my many experiences in supervising and working with Industrial Engineers. It seems that we are prone to spend many hours to prove ourselves mathematically and mechanically correct and yet in our own self-righteousness be so wrong. The wrong is due to the fact that in our defense of our righteousness we forget that we must first secure acceptance on a man-to-man relationship.

We as professional engineers often talk about our profession as being up to 70% human engineering and yet we are inclined to spend most of our available extracurricular or study time away from or on the job learning to be technically correct in the mathematical and physical sciences. We are unable to reduce that which is required for engineering professionalism since most professions were not established until they became scientific. Even though this is true, how many of us have read recently a good book or article on the science of human engineering?

The preceding is not necessarily an indictment of Industrial Engineers. However, we should examine ourselves to see why we are what we are and what we should be. Our education and training as well as those who choose the profession have a basic fault in that the study curricula for engineering require much logical reasoning and proof through mathematical and mechanical problems. Those who dislike detail and mathematics do not normally choose an engineering career. This makes any average engineer normally have two characteristics that set him apart from the average citizen. The engineer will be inclined to be very logical and also be inclined to have more introvert tendencies than the average citizen. These two basic tendencies of the individual engineer who desires to get out of the routine research work and into administrative or management work must be overcome. One may check himself by two simple tests. First, find an occasion to go to a sales meeting and be the only engineer in the crowd. Then a few days later analyze your reaction. Did you thoroughly enjoy that meeting because you became a part of it or because you were able to project your opinions to others? Did you become an accepted part of the group or did you tolerate

COMMITTEE MEETING.

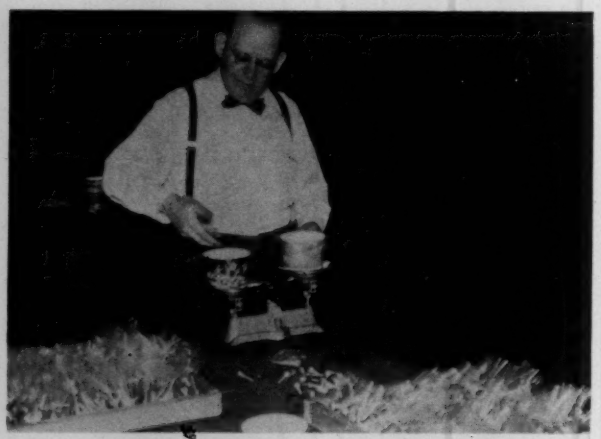


THE ASSEMBLY BELT IN OPERATION.

that which you observed? Second, actively participate in a political party or campaign and try your logic among this group of people. This is a real challenge and will require you to learn the rudiments of handling the nonlogical or illogical problems. If you have a chance to present your views and have any of them accepted by the political group, you are becoming a fast champion of your ego and humility. Perhaps if more engineers participated in politics, it could do good by having politics make more logic than it now enjoys.

Being an unruffled ambivert with the ability to handle the nonlogical human problems that are a part of everyday life is usually the true story behind the more successful men who deal with people.

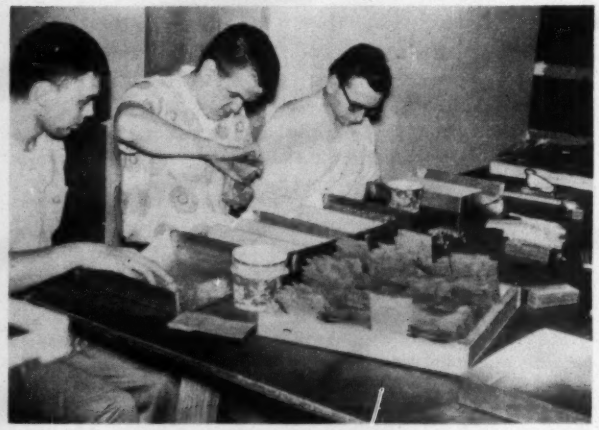
The psychiatrist, psychologists and medical professions offer many opportunities to the Industrial Engineer for securing a better understanding of themselves. In community services activities, one may have exceptional opportunities to gain an insight into human characteristics. Those who work at it will gain very little from this service unless they gain some human relations lessons from participation in the program. By probing into the problems presented by most community services programs, his service will do much for the individual participant in educating him to become more capable in handling the illogical or nonlogical human engineering problems.



WEIGH COUNTING TO GET PROPER COUNT. DEMONSTRATION BY ONE OF THE CENTERS' SUPERVISORS.

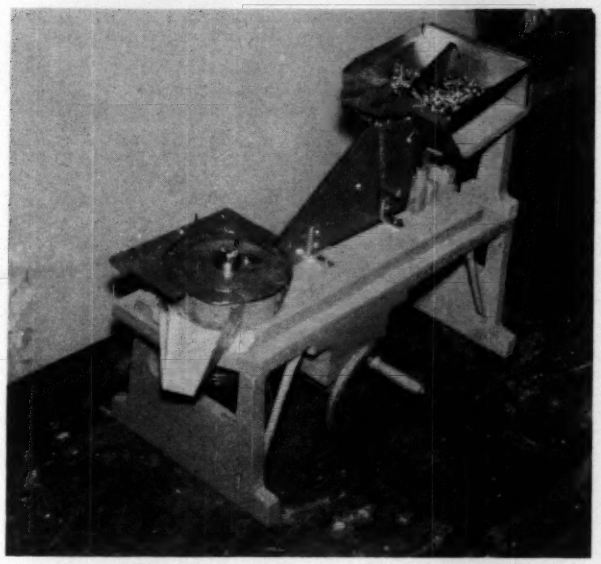
Like an engineer, I have spent a considerable amount of time and words on this point to qualify or prove my contention that the Industrial Engineer should participate in community services activity. Such services will return to the individual participant far more than he can contribute in time or mental exercise. This will also help to improve the public image of the Industrial Engineer. The Industrial Engineering profession is known to the general public as a bunch of efficiency experts. If you do not believe me, go out and ask the next ten people you meet on the street what an Industrial Engineer is and then tell me this statement isn't true. The loose practices and incompetence of some, plus widespread, repeated publication of those ill-founded applications have had and still have an adverse effect on our profession. We, as a professional group, must update the public concept. Civic activities and philanthropic causes are the best methods of gaining the necessary publicity and acceptance of the Industrial Engineering profession on a much higher level than it now enjoys. Who knows, we may even become to the public the human beings we profess to be.

While Region VIII has become one of the more active groups in community services, much remains to be accomplished. The



COUNTING PANS FOR ADVANCED TRAINEES WITH SLIDE-OFF BAGGING CHUTE.

Milwaukee Chapter has set a standard which we hope to improve upon. However, in the case of the Milwaukee Chapter's story, there are many lessons to be gained by other chapters. Imagination, effort and frustrations were common problems in the establishment of its program and yet it is an excellent example of what can be accomplished. Marquette University was approached by the local Vocational Center to assist in making its workshops into a place that could simulate industrial situations more realistically. Erv Spewachek took the problem to the AIIE chapter and presented it. Bob Dimberg, our then chapter president, formed a committee to work on the problems. After meeting with the Vocational Services Director, Dr. Galazan, the committee, then headed by Joe Kutsch, started monthly meetings on shop problems. For a group of neophytes in handling this type of a program, much progress was made. We had the assistance of the Tau Beta Pi, Marquette University Chapter, and enlisted the aid of retired engineers to produce some excellent results in our second and third years of operation. To preserve our momentum, we now have a permanent committee to set policies and keep current assignments progressing. We have a rotating committee which works on the current shop problems. To date we have had very few problems in getting volunteers for an assignment on the committee.



THE COUNTING MACHINE.

The individual committee member has had opportunities to work with mentally retarded, mentally ill, physically handicapped, and emotionally disturbed persons. He has been exposed to and further educated into the real human engineering problems that are posed to the well-trained psychologists on the staff of the Center. In addition, the engineers serving on the committee have had their imagination and creative talent taxed to the full extent of resourcefulness.

How can you get unit counts of ten, eleven or twelve from people whose mental capacity is limited to counting to three? How can we get a person, who is unable to steadily hold himself still for only a fraction of a second, to hold onto an object? How can we increase productivity and not eliminate the therapeutic value of the operation? These and many other problems were handled by those on the committee. Through solving some of these many problems and taking advantage of the discussion of these problems with some excellent psychology majors, the committee learned much more about human engineering problems.

Some of these lessons will never be forgotten. Group recognition of the individual, class distinction through recognition and superior ability were just as predominant in these people as it is among any shop population. The rewards received by the committee members came from the case histories where committee members' ideas turned out to be of exceptional value to the trainees. When these trainees extended themselves beyond their normal capacity for the privilege of becoming a worker on the "belt" or to operate the hand-operated counting machine, it provided deep satisfaction to know that one was a part of the community services committee.

To secure an improvement into our insight into real human relations and also assist the public into getting a more wholesome picture of the Industrial Engineering profession, let's not overlook or underestimate the power of a good, well-directed community services program.

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CALENDAR

1961

October 5-6: Region VIII Conference, Marott Hotel, Indianapolis, Indiana; Indianapolis and Central Indiana Host Chapters; Chairman, Robert Batchelor.

October 8-11: International Systems Meeting of the Systems and Procedures Association, P. O. Box 6175, Cleveland, Ohio.

October 9-11: Communications Conference sponsored by National Office Management Association, Philadelphia, Pennsylvania.

October 10-12: Twelfth National Conference on Standards, Rice Hotel, Houston, Texas; American Standards Association, Inc., 10 East Fortieth Street, New York 16, New York.

October 12-13: Tenth Annual MTM Conference sponsored by Methods Time Measurement Association, Statler-Hilton Hotel, New York, New York.

October 12-13: Region I and II Conference, Pocono Manor Inn, Pennsylvania; Lehigh Valley and Binghamton Host Chapters; Chairman, F. Charles Eichel, Industrial Engineering Department, Riegel Paper Corporation, Milford Mill, Milford, New Jersey.

October 13-14: Region IX Conference, San Antonio, Texas; San Antonio Host Chapter; Col. Cassius McCredie, Box 44, CMU, Lackland Air Force Base, Texas.

October 26-27: American Society of Tool and Manufacturing Engineers 29th Semiannual Meeting in Toronto, Royal York Hotel.

November 5-8: American Documentation Institute Annual Convention, Hotel Somerset, Boston and Kresge Auditorium, Massachusetts Institute of Technology.

November 8-10: First Joint National Meeting of the Operations Research Society of America and The Institute of Management Sciences, Jack Tar Hotel, San Francisco, California.

November 17-18: Region IV Conference, DeSoto Hotel, Savannah, Georgia; Savannah Host Chapter; I. H. Carr, 29 Flinn Drive, Savannah, Georgia.

1962

April 17-19: American Society for Metals Regional Conference and Exhibition, Shamrock Hilton Hotel, Houston, Texas.

May 17, 18, 19: Conference and Convention, Ambassador Hotel, Atlantic City, New Jersey; Metropolitan New Jersey Host Chapter; Chairman, Elio Rotolo, 47 Merker Drive, Edison (Fords P.O.), New Jersey.

September 27, 28, 29: Region X Conference, Hotel Del Coronado, San Diego, California; San Diego Host Chapter; Chairman, L. R. Becht, 701 Balboa Avenue, Coronado, California.

1963

May 9, 10, 11: Fourteenth National Conference and Convention, Denver, Colorado; Rocky Mountain Host Chapter; Chairman, E. D. Williams, Industrial Engineering Department, United Air Lines, Stapleton Field, Denver 7, Colorado.

1964

May 13, 14, 15, 16: Fifteenth National Conference and Convention, Sheraton Hotel, Philadelphia, Pennsylvania; Philadelphia Host Chapter; Richard W. Walton, 804 Old Lincoln Highway, Langhorne, Pennsylvania.

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How Can The AIIE Journal Better Serve You?

You as a reader and user of the Journal of Industrial Engineering are invited to give your opinions. Some questions have been arranged below for easy answering. Your confidence will be respected.

1. Are you pleased with the outside cover style and appearance? Yes ☐ No ☐ (If your answer is no, will you please list a publication that comes closest to describing the style you think is appropriate.) _____

2. If the advertising copy of the *Journal* were increased to 25% of the total pages, do you think the editorial effectiveness of the *Journal* would be increased ☐ decreased ☐ no change ☐.

3. Common subjects of Industrial Engineering are listed. Beside each subject please indicate your preference for more or less emphasis:

	more	less	same
Statistics	☐	☐	☐
Quality Control	☐	☐	☐
Human Engineering	☐	☐	☐
Materials Handling	☐	☐	☐
Information Theory	☐	☐	☐
Time Study Techniques	☐	☐	☐
Group Dynamics	☐	☐	☐
Work Sampling	☐	☐	☐
Symbolic Logic	☐	☐	☐
Inventory	☐	☐	☐
Job Evaluation	☐	☐	☐
(Other) _____	☐	☐	☐
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	more	less	same
Mathematical Models	☐	☐	☐
Historical Subjects	☐	☐	☐
Computers	☐	☐	☐
Linear Programming	☐	☐	☐
Rating and Allowances	☐	☐	☐
Queueing Theory	☐	☐	☐
Motion Study	☐	☐	☐
Electronic Data Processing	☐	☐	☐
Systems	☐	☐	☐
Job Opportunities	☐	☐	☐
Engineering Economy	☐	☐	☐
Professionalism & Ethics	☐	☐	☐
Communications	☐	☐	☐
Recent Readables	☐	☐	☐
Plant Layout	☐	☐	☐
Human Factor	☐	☐	☐
Work Simplification	☐	☐	☐
Editor's Comments	☐	☐	☐

4. What length articles do you favor? (Indicate number of pages below.)

1 ☐ 2–3 ☐ 4–5 ☐ 7–8 ☐ 9–10 ☐
1–2 ☐ 3–4 ☐ 5–6 ☐ 8–9 ☐ 10–11 ☐

_____ Other
(Please specify)

5. Which of the following ratios best describes your preference of technical to non-technical articles?

Technical	0	10	20	30	40	50	60	70	80	90	100
Non-technical	100	90	80	70	60	50	40	30	20	10	0

6. Please list three articles you have read in the *Journal* in the order of your preference:

a. _____
b. _____
c. _____

7. Estimate the percent of the material in the *Journal* that you read. _____%

8. Would you be interested in a refresher course presented as a series of articles in the *Journal*? Yes ☐ No ☐ (If your answer is yes, please list three subjects in the order of your preference.)

a. _____ b. _____ c. _____

9. Do you favor publishing? 40 page monthly ☐ 100 page bimonthly ☐ Other _____

10. What questions have been overlooked? _____

11. Fellow ☐ Member ☐ Associate ☐ Affiliate ☐ Name _____
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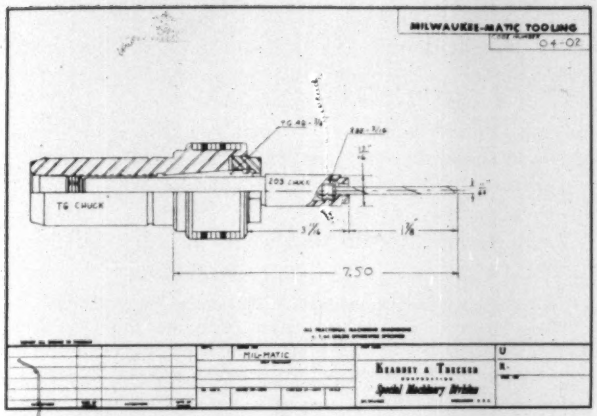

FIGURE 2. Tool Sketch.

There was a question whether the machines should be located in the Standard Machine Division, which has medium lot size production, or the Special Machinery Division, which has one piece and small lot size production. The machine lends itself better to medium lot size production than to one piece type production. However, the personnel of the Special Machinery Division were much more familiar with the Milwaukee-Matic and tape controlled machines in general because all tape controlled machines have been designed and built in this division. It was felt, at least for the beginning, that it would be better to have the machines located in a plant where personnel were familiar with tape control. Another advantage was that the machines could be erected and tested on the foundations to be used for production.

STANDARDIZATION OF TOOLING

Because the Milwaukee-Matic could use a great variety of tools and a wide variety of parts would be run, it was apparent that standardization of tooling was necessary. If this were not done, the results would be too many tools, too great a tool cost and difficulty for the programmers to establish the proper tool requirements. Every effort was made to use standard length tools wherever possible so that the cost would be much less and replacement no problem. Various vendors were contacted to determine what would best fit our needs as a standard extension, or holder, for the Milwaukee-Matic. Along with the tool standardization, a tool coding system had to be set up. With the Milwaukee-Matic, 961 different codings are possible. When a tool is assigned a code number, a sketch is also made of the tool, providing all the information required to set up a duplicate of it. The sketch lists the size, length, holder, collet, and extension if required. Length settings for various tools, such as drills, taps, reamers, spotdrills and boring bars, were standardized to reduce the number of codes and sketches needed. Because these items are standard, it is not difficult for the programmer or tool designer to determine what holder, extension and tool must be used and what clearances are required to use it. The engineering department can also aid in the reduction of tool costs by standardizing on drill sizes, counterbore sizes, etc. (Figure 2).

CRIB FACILITIES

A separate crib was set up to service the tape controlled machines. Tool control is very important because when a job is repeated, all the tools must be set in the same way as during the first time as far as lengths, sizes and type of holder or extension are concerned. It was felt that, to insure this degree of control, a separate crib was needed to store tools, holders, extensions, collets and any special tools (Figure 3).

TOOL SETTING

Tool setting facilities were required because all tools and fixtures are set up before the operation is started on the machine. This is one of the time-saving features of tape controlled machines; virtually no setup time is used that interrupts the cycle operation of the machine. To preset the tools, a tool setting machine was designed by the engineering department; with it, the tool setter can accurately set a tool for length and diameter. An area was set aside in the tool crib as a work station for the tool setter (Figure 4).

PALLETS

The Milwaukee-Matic is designed so that work is shuttled to the working station of the machine on pallets. The pallets for the Number II machine are 18″ × 18″. The jobs are set up on the pallets in the crib. When the job is ready to run, the pallets and tools are carted to the machine and placed on the load station of the machine. All pallets are interchangeable so it does not matter on which pallet the job is arranged (Figures 5 and 6).

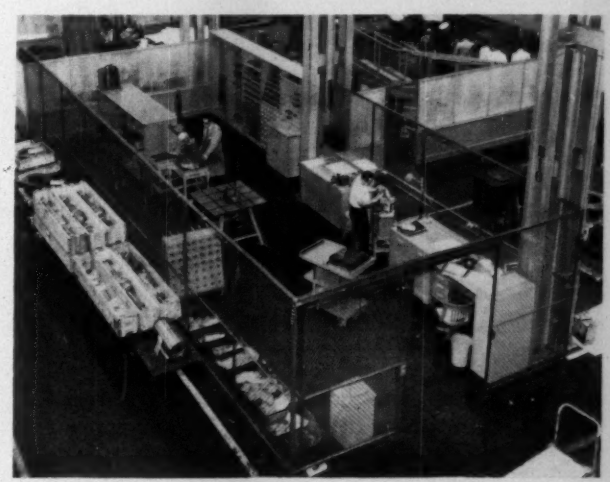

FIGURE 3. Tool Crib.

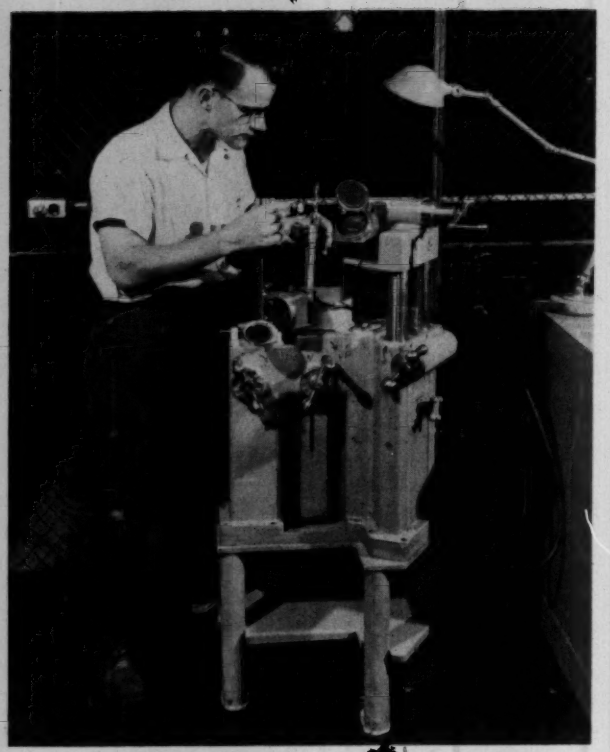

FIGURE 4. Tool Setting Machine.

FIXTURES

The tool designer of the fixtures for the Milwaukee-Matic must be familiar with the machine and also the type of cutting tools, holders, etc., that are used on it. The fixture should be designed so that as many surfaces as possible can be presented to the spindle in the same operation and also that clearance be insured for all cutting tools and holders. A plastic template of the machine spindle nose (full or half size) is used in planning for tool clearances from the part print. One tool designer was assigned to specialize in Milwaukee-Matic fixture design.

INDUSTRIAL ENGINEERING DEPARTMENT PERSONNEL

In planning for the needs of the Industrial Engineering Department, it was felt that we would require a program engineer, programmers, a tool designer and an Industrial Engineer to plan the needs and set up the shop operating department.

PROGRAM ENGINEER

Initially, the program engineer was responsible for setting up all the procedures and forms to be used in programming operations to the machine. After procedures and forms were set up, he was to be responsible for the direction of the programming section, including the programmers.

PROGRAMMERS

The individuals selected to do the programming must know the machining practices for the type of machine to be programmed. This would include the manner in which the part must be held, type of tools required, speeds and feeds and the ability to recognize nonstandard conditions in workpiece or tooling. They should like detail and be able to do accurate work.

The duties of a programmer would include the following:

1. Estimate running time on the Milwaukee-Matic to provide economic justification of the operation being run on a tape controlled machine versus conventional methods.
2. Determine how the part is to be held and recommend type of holding fixture required.
3. Determine cutting tools and related adapters required to perform the operation and make up operation tool card and individual tool sketches.
4. Program the sequence of cuts, tools to be used, machine movements required, speeds and feeds and any auxiliary functions such as manual tool changes and coolant.
5. Add program reference points to the blueprint.
6. Work with the technician at the machine while the first piece is being run and make any tape adjustments required.

INDUSTRIAL ENGINEER

In setting up the operating phase of tape controlled machines, the Industrial Engineer is concerned with departmental layout, tool standardization, tool control, tool

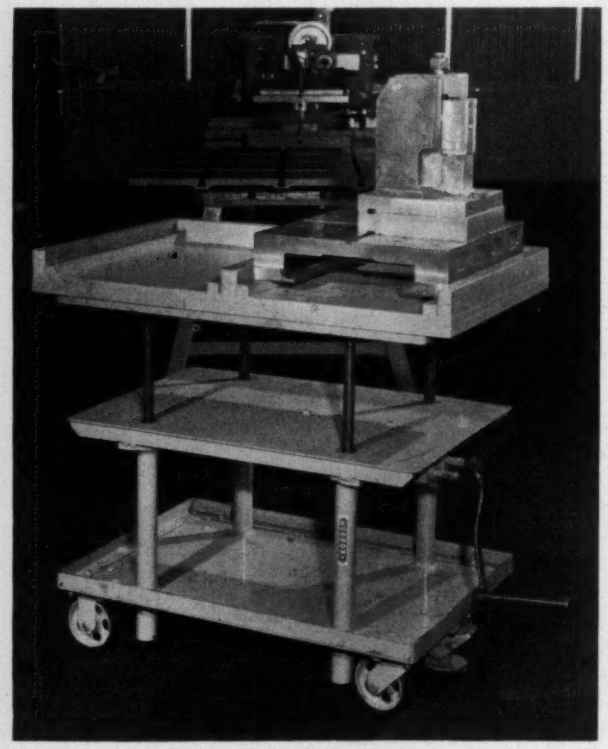

FIGURE 5. Pallet Cart and Pallet.

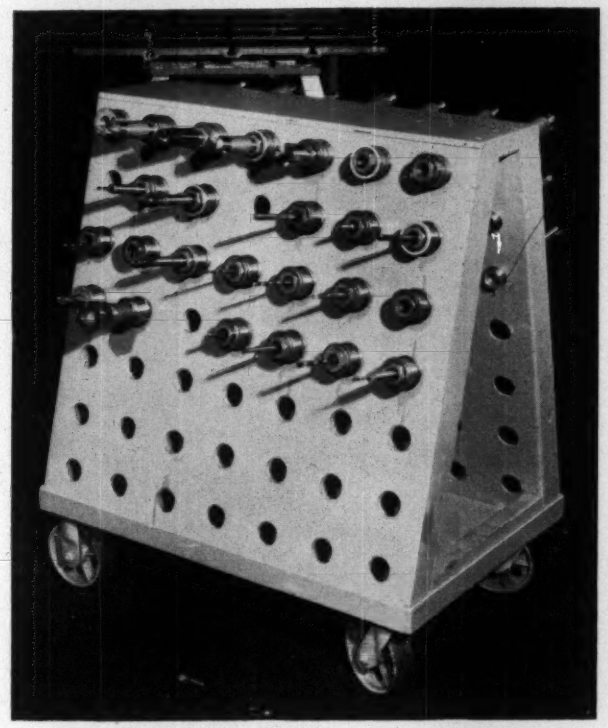

FIGURE 6. Tool Cart and Tools.

storage, tool setting, machine operation, machine maintenance and personnel requirements. In order to determine what should be done in these areas, he must first become familiar with the capabilities and limitations of the machine. He also must become familiar with programming in order that the tools and tool standardization will fit in with the programming requirements.

SHOP DEPARTMENT PERSONNEL

The anticipated personnel requirements for the shop department were technicians, tool setters, loaders and inspectors. The men assigned to these jobs would be part of the shop unit.

TECHNICIAN

The technican is a skilled machinist whose duties include the following:

1. Direct the efforts of the loaders and tool setters and assist them in performing their duties.
2. Work with the programmers in proving out new tapes.
3. Be responsible for running jobs in the order established by production control.
4. Exercise close supervision of the loader when the first piece of a lot is run.

TOOL SETTER

The tool setter is a semi-skilled mechanic whose duties would include the following:

1. Determine tooling requirements from the setup instruction cards and set up the tools as prescribed on the tool sketch. Use the tool setting machine when required.
2. Set up fixtures and workpieces on the pallet.
3. Disassemble fixtures from pallets, disassemble cutting tools and return them to proper locations.

LOADER

The loader is a semi-skilled mechanic whose duties include the following:

1. Load tools, pallets and tapes for the operation to be run.
2. Load and unload workpieces and operate the machine.
3. Perform inspection operations that can be done at the machine.
4. Refer operating or quality problems to the technician.
5. Operate one or possibly more machines.

INSPECTOR

The skill requirements of the inspector would be no different than those of an inspector in the normal machine shop. His duties would include the following:

1. Inspect the first piece of the lot completely.
2. Spot check, on subsequent pieces, dimensions that cannot be inspected by the loader.

PRODUCTION CONTROL

Production control entered the planning stage to the degree that provisions had to be made for test lots to prove out tapes and to release scheduled production lots after tapes had been proven.

PROBLEMS ENCOUNTERED AND CHANGES REQUIRED

After proving out the first few tapes, it was apparent that the time a job was on the machine to prove out the tapes had to be reduced. When the operation was being proved out on the machine, an error in the programming could cause an accident. Sufficient clearances were not always provided in the fixture for tools, or workpiece clearances were not as planned for, especially on castings. To reduce the downtime on the machine, a "Program Checking Machine" was designed and built (Figure 7). On this machine, which consists of a rotary table and mock spindle, the programmer can simulate the entire operation with the workpiece and fixture mounted on the rotary table. By doing this, errors are found before the job is on the machine and the necessity of a "dry run" cycle (a cycle without a workpiece) is eliminated.

Another technique now being used in tape prove-out is the block stop method. In proving out a tape using the block stop method, the machine is stopped at each line of information. This gives the programmer and the technician an opportunity to determine from the program what the next move is and also to measure the distance that the machine will move. By measuring critical moves before the machine moves, costly accidents are eliminated. This method also gives the programmer an opportunity to observe the tools cutting; he can then make speed or feed adjustments to the tape if necessary.

Initially efforts were made to make two station fixtures wherever possible, in order that as much work as possible could be performed in one shuttle to the working station. In many cases, this resulted in a costly fixture due to complications in holding the pieces and still providing clearances for tools. Because a shuttle only takes 20 seconds, the fixture designs were changed to simpler fixtures and several operations. This concept is especially applicable to our small and medium lot sizes.

To reduce tooling costs still further, a universal fixture was designed (Figure 8). This fixture was designed to take work that can be located on two edges and secured on the other two. Workpieces of that type, and there are many, use only the universal fixture, rather than special tooling. This fixture has the mounting slides for the locators and jaws graduated so that a part can be located in the same position in the future. This fixture can also be used as a base for mounting sub-fixtures.

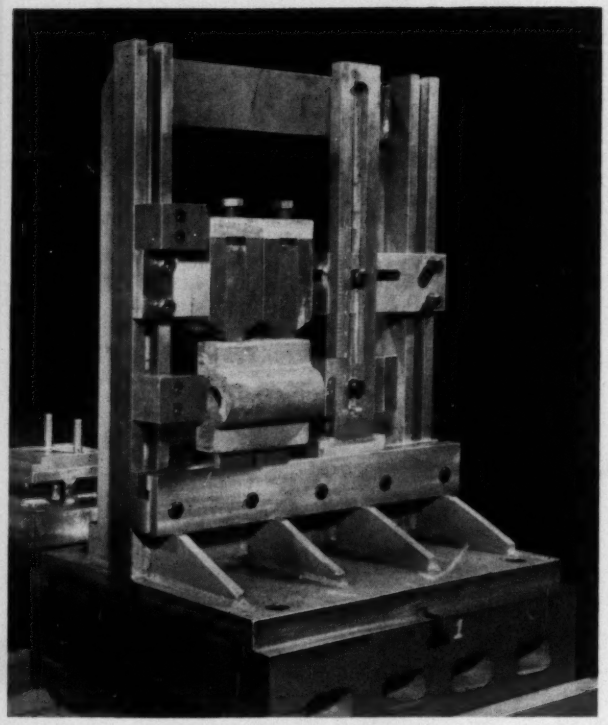

FIGURE 8. Universal Fixture.

CONCLUSION

Judging from the results we have experienced and the results of other manufacturers using tape controlled machines, these machines will become a substantial influence on our manufacturing methods and personnel requirements. The introduction of tape controlled machines in a company will affect some departments more than others but will have an important influence on manufacturing and Industrial Engineering.

Manufacturing must train operating and maintenance personnel. Maintenance will play a substantial role in the success of a tape control department since, as a rule, tape controlled machines are quite expensive and it is important that they be operating as much as possible, preferably three shifts. It is important that a good preventive maintenance schedule be set up and maintained and that qualified personnel be available to take care of breakdowns that occur. Costly and time consuming repairs can also be caused by errors in tool design, tool setting and programming.

The majority of the companies using tape controlled machines have assigned to the Industrial Engineering Department the responsibility of setting up operating procedures and providing tapes for the machines. This means that to a great degree the effectiveness of the Industrial Engineering Department will determine how much or how little a company can benefit from tape controlled machines.

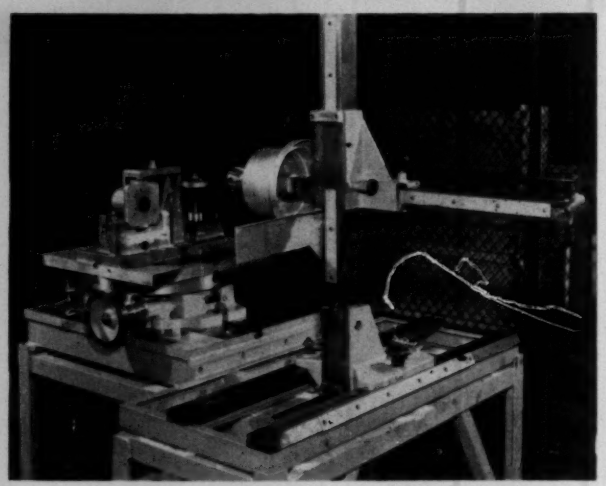

FIGURE 7. Program Checking Machine.

PROFESSOR OF
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Ph.D. degree. Teaching and Industrial experience required. Operations Research specialization preferred. Salary appropriate to qualifications. Department of Industrial Engineering, Syracuse University, Syracuse 10, New York.

Planning Work Sampling Studies for Efficient Sampling and Processing of the Data

by C. F. B. WILDING-WHITE[1]

Assistant Professor of Management Engineering, Rensselaer Polytechnic Institute

WORK SAMPLING has developed in recent years into a powerful engineering tool for gathering information about a variety of activities, ranging from simple repetitive work to managerial and creative skills. The scope of activities subject to this kind of analysis is evident upon examining some recently published articles which record studies carried out on potting plants in a nursery (7), materials handling (10), aircraft maintenance (2) and nursing in hospitals (4) (12). Managerial and creative skills studied include an operating management (3), an engineering design activity (13), and university faculty (11).

In view of the variety of tasks which can be studied with work sampling, it is not surprising that it has been found necessary to tailor each work sampling study to fit the particular activities being observed in order to obtain the desired information. In some respects this is much the same as any time study which requires considerable preliminary investigation, analysis and definition of the job and its elements. Work sampling differs from time study, however, in that to make efficient use of the observer's time he must usually sample several workers, machines, or other items under scrutiny during each round of observations. Because of the physical difficulties involved, and in order to achieve valuable results and efficiency in performing the study, sound planning would be required which would include the establishment of as many common elements as possible. In work sampling, in spite of such typical planning, an additional problem is encountered. This is the astonishing rapidity with which information accumulates. This information must be properly segregated, tabulated, and statistically evaluated as quickly as it is gathered because it is necessary to analyze the cumulative data in order to determine if the direction of the study needs modification and to establish the duration of the period of observation. Furthermore, control charts of selective elements are often desirable, not only to evaluate the stability of the work under observation, but also to maintain the interest of both the observers and the observed, in much the same way that they prove effective in quality control, and for these purposes control charts must be kept up to date.

EFFECTIVE HANDLING OF SAMPLING DATA

Processing of sampling data is essentially mechanical in nature and therefore, when done manually, is sheer drudgery. This discourages the participants, unduly increases the cost, and hampers the potential value of the study by restricting the number of the elements into which the work under observation can conveniently be subdivided, since for adequate statistical accuracy, the greater the number of elements or subsampling periods, the greater the total number of required observations. Extensive subdivision into elements and subsamples greatly increases the amount of data and correspondingly multiplies the data processing work. This suggests a need for simplification and standardization of work sampling methods, forms and data processing techniques, a subject which has not received appropriate attention in current texts (1) (5) (6) (8).

The problem, then, is to devise a nonmanual data processing method which is sufficiently flexible so that it can be easily adapted to assimilate data from any work sampling study with a minimum necessary amount of redesign. Some engineers have recognized this problem and have attempted solutions appropriate to the data processing equipment available. Typical methods include the use of mark-sensing machine tabulated cards (1) (6) and keysort cards (9) which require no mechanical handling. A claim for use of cards is that data can be recorded directly by the observers while sampling, thus eliminating any subsequent card punching from data sheets. This claim was evaluated as part of a pilot work sampling study applied to a complex group of operations in a commercial bank under the direction of the author and of Professor Harold Martin at the Rensselaer Poly-

[1] Current President of the Capital-Berkshire Chapter of the American Institute of Industrial Engineers.

technic Institute's Management Engineering Department with the assistance of eighteen students, as part of a laboratory exercise in a work measurement course. Major emphasis during this study was placed on developing efficient ways of recording and processing the sampling data.

CHARACTER OF THE STUDY

The study covered operations, banking machines and customers in two areas of a commercial bank. Seventeen activities were observed on the main bank floor, consisting of tellers, customer service time and queues, and the operating status of savings account machines. In the bookkeeping department 18 activities were observed, namely, bookkeepers, bookkeeping and addressograph machines. In the two departments a total of 35 activities were under observation including 23 employees, several machines and customer queues. In general, individual observers were assigned during a sampling period to each of the two areas under study because of the physical distance separating the areas and because of security restrictions placed upon frequency of access to the teller enclosures. Within each area, however, all the activities were sampled by the observer on duty and the two areas were treated as a single study.

The preliminary analysis revealed an unexpected complexity in the work hours, work mix and customer load. The work day started at 7:30 on Monday but at 8:30 on other days. It finished at 5:30 on Monday, at 4:30 on Tuesday, Wednesday and Thursday and at 6:30 on Friday. Doors opened to customers from 9 to 2 on the first four days of the week and from 9 to 5 on Friday. The tellers' work load and element mix were found to vary considerably with the presence or absence of customers and with the time of day, day of week, and even with the season. The latter factors also affected customer service time and queues. Consequently it was decided to subdivide the day into subsample periods of one hour each, starting at 7:30 (Monday only) and finishing at 6:30 (Friday only). Of the 11 periods established, the maximum number on any one day (Monday) was 10 and the minimum (Tuesday, Wednesday, Thursday) was 8, to most of which observers were assigned for as complete a picture of the banking operations under study as possible.

The organizers of the study and bank officials at the start of the study were not precisely sure how they wanted the data subdivided so that it was necessary to segregate each activity into numerous elements which could later, after analysis of the preliminary results, be grouped in whatever manner seemed most effective. Furthermore, with adequate data processing methods, element subdivision provided for future regrouping of the data as desired. Thirty-five elements were established and recorded on cards for easy reference by observers until memorized. To the maximum extent possible, an element number represented similar work at all work stations under observation. The fact that the number of elements and work stations were both 35 was sheer coincidence.

The number of observers was 18. This is a somewhat greater number than normal for such a study but was necessary in order to give each member of the class some sampling experience and in order to cover as many of the sampling periods as possible without creating an unduly heavy burden on the student observers. Each observer's target was 100 observations per hourly sampling period. Thus, depending upon the day of the week, up to 2000 observations could be made in a day, that is, 100 per hour in each bank section.

From the above description, it should be apparent, as it was at an early point to the organizers of the study, that a simple, rapid and fool-proof means of recording the observations was required, combined with a sophisticated method for digesting the data. These objectives were substantially achieved during the study and are described in the remainder of this article.

RECORDING THE OBSERVATIONS

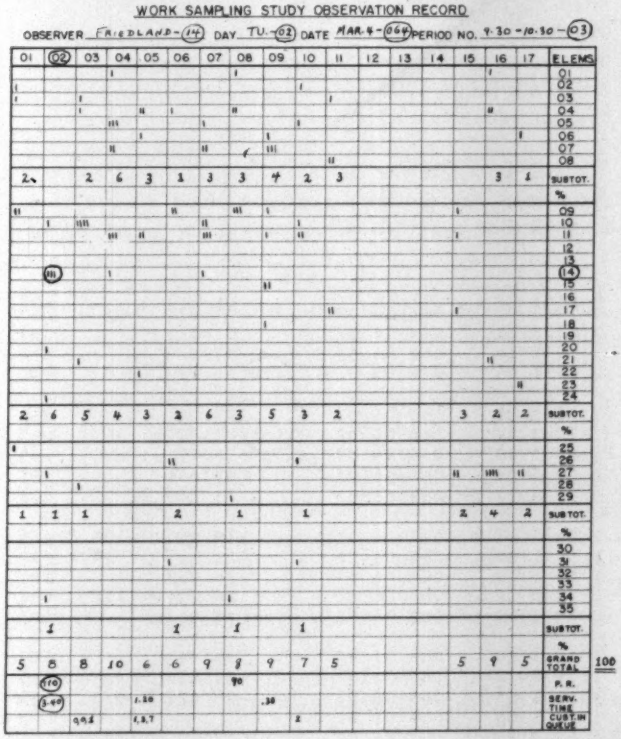
Since Rensselaer Polytechnic Institute is equipped with a computer center in which are available standard sorting and tabulation equipment as well as digital and analog computers, it seemed best to record observations on punch cards for subsequent digestion by these machines. In keeping with the previously referred to suggestions that observations be recorded on cards when made, the observers attempted to record observations directly on hand punched tabulating cards using the handy IBM Portapunch, but they quickly found this device unsatisfactory. Each observer aimed at 100 observations per period, sampling continuously during the period, selecting the worker, machine or queue to be observed by means of a random number table with numbers from 0 to 35. Only one activity observation could be punched into each card used which, in addition, required the punching of four or more additional items of information (week day, observer, day of year, period number). These items could have been pre-punched, but because of the number of observers and observation periods involved, pre-punching was judged somewhat cumbersome and likely to result in data being entered on the wrong card. The net result of using cards was to make clerical workers of the observers and considerably reduce the number of observations which they could obtain in each period. Portapunch cards also proved unsatisfactory mechanically because they had to be reproduced onto standard cards. Attempts to do this mechanically using an IBM 514 reproducer failed because of the varying card thickness resulting from the manufacturer's semi-punching of the cards to facilitate hand punching. A successful alternative was found by using a 402 accounting machine tabulator wired to the 514 reproducer. The tabulator read the

cards which were then duplicated by the reproducer. This expedient, however, was slow and laborious. Other objections to direct punching of cards have been expressed by at least one writer (5).

The solution to these difficulties was found in combining the best features of punched cards and a manual data sheet. By recording observations directly on a well designed data sheet maximum observer efficiency resulted in terms of accuracy and quantity of observations per period and reduction of clerical work. Data on the sheets were then efficiently and economically punched directly into a reduced number of standard cards, by experienced key punch operators, recording several observations on each card with no significant loss in data flexibility.

DESIGN OF DATA SHEET AND CARDS

Two data sheets were designed during the study, Figures 1 and 2, the latter representing a considerable improvement over the first. Both are shown to demonstrate the importance of very careful attention to this matter. A well designed data sheet must provide, if possible, space for all daily sampling periods and work stations


WORK SAMPLING STUDY OBSERVATION RECORD

OBSERVER FRIEDLAND-(14) DAY TU.-(02) DATE MAR. 4-(064) PERIOD NO. 9.30-10.30-(03)

01	(02)	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	ELEMS.
			1				1								1		01
1									1								02
1		1								1							03
		1		11	1		11								11		04
			111			1		1									05
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			11			11	4	111									07
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11					11		111	1						1			09
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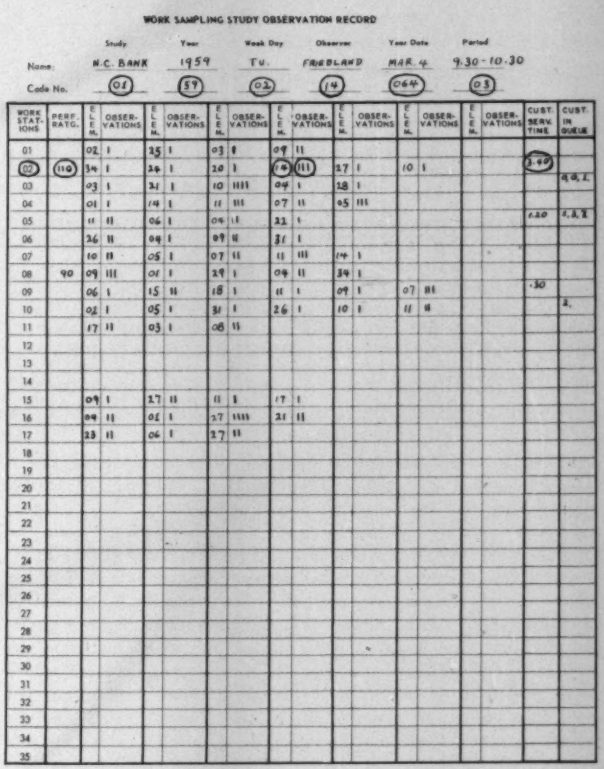
5	8	8	10	6	6	9	8	9	7	5				5	9	5	GRAND TOTAL 100
	(10)						90										P. R.
	(.40)			1.20				.30									SERV. TIME
		9,11		4,8,7				2									CUST. IN QUEUE

Work stations are arranged horizontally across top of form. Elements, performance rating, customer service time and queues are listed vertically. Circled items were posted to the tabulating card in Figure 3. A similar data sheet was used for observations in the Bookkeeping Department.

FIGURE 1. Sampling Data Sheet for Bank Hall.


WORK SAMPLING STUDY OBSERVATION RECORD

Name: Study: N.C. BANK; Year: 1959; Week Day: TU.; Observer: FRIEDLAND; Year Date: MAR. 4; Period: 9.30-10.30

Code No.: (01) (59) (02) (14) (064) (03)

WORK STATIONS	PERF. RATG.	ELEM.	OBSERVATIONS	ELEM.	OBSERVATIONS	ELEM.	OBSERVATIONS	ELEM.	OBSERVATIONS	ELEM.	OBSERVATIONS	ELEM.	OBSERVATIONS	ELEM.	OBSERVATIONS	CUST. SERV. TIME	CUST. IN QUEUE
01		02	1	35	1	03	1	09	11								
(02)	(110)	34	1	24	1	20	1	(14)	(111)	27	1	10	1			(.40)	
03		03	1	31	1	10	1111	04	1	28	1						4,8,2
04		01	1	14	1	11	111	07	11	05	111						
05		11	11	06	1	04	11	32	1							1.20	4,8,7
06		26	11	04	1	09	11	31	1								
07		10	11	05	1	07	11	11	111	14	1						
08	90	09	111	01	1	29	1	04	11	34	1						
09		06	1	15	11	18	1	11	1	09	1	07	111			.30	
10		02	1	05	1	31	1	26	1	10	1	11	11				2.
11		17	11	03	1	08	11										
12																	
13																	
14																	
15		09	1	27	11	11	1	17	1								
16		04	11	01	1	27	1111	21	11								
17		23	11	06	1	27	11										
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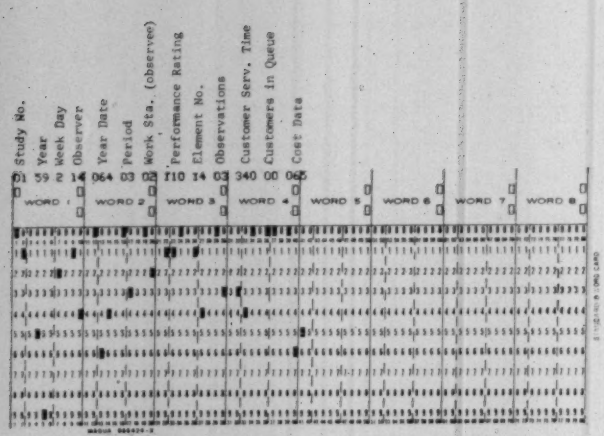
A single sheet suffices for all 35 work stations and posting to the tabulating card in Figure 3 is much simplified.

FIGURE 2. Improved Sampling Data Sheet with the Same Sampling Observations as in Figure 1.

and elements to be sampled. In addition it must be easy to use by both observers and subsequent key punch operators. The scope of this study manifestly made it impossible to achieve all of these objectives on a single sheet and therefore in both designs a new data sheet was used for each hourly sampling period. The first sheet is a matrix with horizontal lines representing numbered work elements and vertical columns, the work station numbers corresponding to those on the random number table used. Two identical sheets were needed, one covering commercial tellers (1-8), savings tellers (9-11), customer service time and queues (12-14) and savings account bookkeeping machines (15-17) in the main bank floor. The other sheet covered bookkeepers, bookkeeping and addressograph machines (18-35) in the bookkeeping department. To enter an observation a vertical mark was made in the box corresponding to the work element and station after each observation. Elements on the data sheet were grouped into four categories thought to be of the greatest preliminary value to management, as follows: productive work, non-productive work, non-work unavoidable, non-work avoidable. No special significance was given to this grouping and it was not reflected in



Punched into this tabulating card are observations made on a Tuesday (day 2 of week) by observer 14 on the 64th day of the year during the 3rd sampling period of the day. Data on this card were quickly posted by a key punch operator from the original work sampling study observation sheet shown in Figures 1 and 2. One such card is needed for each element box used by an observer during a sampling period. At Work Station 2, element 14 was observed 3 times, as well as a performance rating and queue information. One hundred observations and additional data recorded in one sampling period on the sampling observation record were posted to 64 tabulating cards. With more observations per sampling period, or a reduction in the element subdivision or sampling periods per day, the saving in tabulating cards increases correspondingly.

FIGURE 3. Tabulating Card.

punching the cards. At the end of each period of observation, the observer spent a few minutes totaling the subgroups and the total number of observations made. Again, this was not necessary but served only to keep observers immediately informed as to the results of the period just completed. During each day a maximum of 16 to 20 sheets were used, depending upon the number of sampling periods in the day. On the following day the information was transferred to standard tabulating cards by an experienced key punch operator using an IBM 026 Key Punch. One card was used for each square containing one or more observations on the data sheet, hence for each data sheet as many cards were required as there were element squares containing observations. This data sheet had two serious deficiencies. Considerable searching for the appropriate box by the observer slowed his work and promoted errors. The key punch operator had even more difficulties since neither the repetitive information nor the element observations could be read off the sheet in the sequence in which the information was to be punched into the card, Figure 3, a prime requisite for simplification of this task.

The redesigned data sheet, Figure 2, overcomes the above difficulties and provides space for all 35 work stations on one sheet. When using this data sheet, the observer selected the work station number from the random number table and immediately located it in the vertical column. He then made his observation and identified the work element number which, if previously unrecorded in the current observation period, he entered by means of a vertical mark in the first available box to the right of the work station number. If the element had been previously observed, another mark in the appropriate box was sufficient to record the observation. Special columns were provided for performance ratings and customer service or queues. With this form, the number of vertical columns needed varies with the quantity of elements into which the work is subdivided. In this study the subdivision was large but because there were also many work stations under observation, it was found that seven element columns provided for a greater possibility of different element appearances under the same work station than could be reasonably expected to occur in any 100 observations. In adapting this very satisfactory form to other studies, attention must be given to the problem of providing the appropriate number of element columns. The six items of information across the top of the data sheet were arranged in the same order as the first six items on the tabulating card shown in Figure 3, which

Study No.	Year	Week Day	Observer	Year Date	Period	Work Sta. (observee)	Performance Rating	Element No.	Observations	Customer Serv. Time	Customers in Queue	Cost Data
1	59	1	05	064	06	02		01	01			065
1	59	3	20	066	06	02		01	01			065
1	59	3	21	063	06	02		01	01			065
1	59	1	14	063	06	02		02	02			065
1	59	1	05	064	06	02	110	03	01			065
1	59	3	20	066	06	02		03	01			065
1	59	3	12	065	06	02	105	03	01			065
1	59	3	20	066	06	02		04	01			065
1	59	1	05	064	06	02		09	03			065
1	59	3	12	065	06	02		15	01			065
1	59	3	21	063	06	02		19	01	100	1	065
1	59	1	05	064	06	02		23	01	33	1	065
1	59	3	20	067	06	02		24	01			065
1	59	3	12	065	06	02		28	01	150		065
1	59	2	19	063	06	02		28	01			065
1	59	3	20	066	06	02		33	04			065
1	59	3	12	065	06	02		33	01			065
1	59	1	05	063	06	02		33	02	050		065
1	59	1	05	064	06	02						
1	59	3	20	067	06	02						

This is for Work Station 2 (commercial teller) and tabulates all data for Period 6 for one week. These data are summarized and further developed in Figure 5.

FIGURE 4. A Typical Tabulation of the Sampling Data.

BANK SAMPLING STUDY - SAMPLING DATA SUMMARY

WORK STATION(S) NO. (2)	PRODUCTIVE WORK ELEMENTS: 01 THRU 08			NON-PRODUCTIVE WORK ELEMENTS: 09 THRU 24			NON-WORK UNAVOIDABLE ELEMENTS: 25 THRU 29			NON-WORK AVOIDABLE ELEMENTS: 30 THRU 35			TOTAL OBSERVATIONS	AVG. P. R. %
PERIOD NO.	NO. OF OBSV.	P_p %	2 σ %	NO. OF OBSV.	P_n %	2 σ %	NO. OF OBSV.	P_u %	2 σ %	NO. OF OBSV.	P_a %	2 σ %		
1	5			23			0			0			28	
2	27			26			1			1			55	109
3	4			5			2			2			13	
4	2			2			1			1			6	110
5	3			0			1			9			13	
(6)	(7)			(7)			(2)			(7)			(23)	(107.5)
7	13			31			2			0			46	98
8	0			4			6			3			13	
9	12			7			0			0			19	
10	0			1			0			0			1	
11	3			0			1			5			9	
SUMMARIES	78			106			14			28			228	103

This shows cumulative observations for one week of Work Station 2 (commercial teller) subdivided by observation periods but with the elements grouped into four categories. The circled values for Period 6 were obtained from the machine tabulation shown in Figure 4. The sampling error has been omitted because of insufficient data.

FIGURE 5. A Typical Preliminary Summary.

facilitated key punching since these items were unchanged for all cards punched from data on one sheet. After punching (or prepunching) these items, the operator moved vertically down the work station column and horizontally across the sheet at each work station, counting and recording on a separate card the total observations in each box. Performance ratings and queue data were entered in any one of the cards for the pertinent work station. If desired, they could have been recorded on separate cards. The arrangement of data on the improved sheet and first 10 column assignments on the tabulating card should be adaptable to other work sampling studies with no rearrangement. This is probably not true of the last three columns which applied specifically to this study. Only half of the available standard columns were used, leaving additional space for other desired information, an added advantage over use of Portapunch cards which have only half as many columns. In this study the hourly cost of each operation was added as a final item by the key punch operator from a separate source data sheet. In an industrial study production quantities, standard hours per unit or other similar information could be added using the spare columns. For studies of other activities, other items might be desired.

Figure 4 shows a typical tabulation made from the tabulating cards. Cards for one week were sorted by period (period 6) and work station (station 2) and then tabulated by element sequence. Twenty-five observations occurred in this week. The data can, of course, be sorted and tabulated in an almost infinite number of combinations. For instance, this tabulation has been retabulated into four element groups and is shown summarized in Figure 5. Another tabulation is shown summarized in Figure 6. Here a cumulative summary of work stations 1-8 (commercial tellers), again by element groups, is shown. Here enough data were available to calculate the sampling margin of error at the 2 sigma confidence level. As management studies the results and becomes more aware of the information that is being provided, a desire for more detailed information can be satisfied by resorting the cards and regrouping the elements in any desired manner. The resulting statistical accuracy of the new element groups leads to a decision about how long to continue sampling. If properly planned at the start, it should never be necessary to re-start the study to gather more detailed information. The information is all available by retabulating the cards.

Because of the limitations imposed upon this study (available laboratory hours of observers) it was not possible to continue sampling long enough to make effective use of the data. The study did serve as a vehicle for developing appropriate simplified work sampling methods.

ADVANTAGES

1. Observers are unhampered by unwieldy direct punching devices and obtain more data during each sampling tour.
2. The data are efficiently punched into a reduced number of cards by an expert key punch operator.
3. The data can be well subdivided by elements and subsample periods permitting a very thorough analysis of the work being studied.
4. Flexibility is introduced permitting the data to be easily retabulated or grouped as desired.
5. The data are ideally recorded for programming on a computer if desired.
6. The basic column assignments on the punch cards continue to be used for subsequent work sampling studies, but remaining

BANK SAMPLING STUDY - SAMPLING DATA SUMMARY

WORK STATION(S) 1 THRU 8 TOGETHER	PRODUCTIVE WORK ELEMENTS: 01 THRU 08			NON-PRODUCTIVE WORK ELEMENTS: 09 THRU 24			NON-WORK UNAVOIDABLE ELEMENTS: 25 THRU 29			NON-WORK AVOIDABLE ELEMENTS: 30 THRU 35			TOTAL OBSERVATIONS	AVG. P. R. %
PERIOD NO.	NO. OF OBSV.	P_p %	2 σ %	NO. OF OBSV.	P_n %	2 σ %	NO. OF OBSV.	P_u %	2 σ %	NO. OF OBSV.	P_a %	2 σ %		
1	20	9.48	4.02	176	85.4	5.12	4	1.90	1.88	11	5.22	3.06	211	
2	117	52.0	4.88	221	60.9	5.12	14	4.58	2.14	12	3.28	1.86	366	101
3	33	42.5	11.2	29	37.2	10.9	9	11.5	7.24	7	8.98	6.44	78	107
4	37	42.9	10.6	34	39.1	10.4	4	4.60	4.48	12	13.8	7.4	87	101
5	98	42.9	6.92	92	22.5	5.00	6	2.60	2.10	79	32.4	6.16	281	111
6	122	39.6	5.58	108	35.0	5.44	20	6.49	2.80	58	18.8	4.46	308	102
7	54	17.8	4.40	227	74.7	5.00	13	4.28	2.32	10	3.29	2.05	304	95
8	2	2.44	3.42	65	74.8	9.30	6	7.92	3.76	11	13.4	6.54	82	95
9	59	41.3	8.22	67	46.8	8.54	12	8.38	6.16	5	3.9	3.08	143	75
10	21	38.2	12.1	17	30.9	12.9	4	7.27	7.02	13	23.6	11.6	55	
11	25	35.7	11.4	14	20.0	9.56	9	12.8	7.98	22	34.4	11.1	70	
SUMMARIES	588	30.4	2.08	1008	52.0	2.24	103	5.32	1.02	236	12.2	1.49	1935	104

This shows cumulative observations for one week of Work Stations 1-8 together, all commercial tellers. This summary resulted from machine tabulations similar to those in Figure 4, but modified for the desired result.

FIGURE 6. A Typical Summary.

free columns are available for special features often encountered in new sampling studies.

7. Computer programs for analysis, once developed for these cards, can be used for other studies with little modification.

SUMMARY

Work sampling studies are usually complex. To be effective, therefore, preparation for the study should not need to be unduly prolonged, and provision should be made for rapid collection and processing of the data. This would reduce cost, facilitate motivation of the observers and give guidance to the study by providing for preparation of up-to-date summaries and control charts. Finally, flexibility should be sought by collecting and storing data in a manner designed to permit future extraction of more or better information from past observations. To achieve these ends, standardization of work sampling methods, forms, and data processing techniques are needed. An additional aim should be easy adaptation of sampling methods from one study to another.

A pilot work sampling study by a large group of observers on a complicated group of operations in a commercial bank served as a vehicle for developing some solutions to the above objectives. Recording data in mechanical tabulating cards proved effective, but a well designed observation sheet was found superior in several ways to direct card punching by the observers. Mechanical tabulation resulted in rapid digestion of data and up-to-date summaries. Extensive subdivision of the operations by work elements and of the work day into subsampling periods, coupled with use of tabulating cards, resulted in an ability to extract an almost unlimited variety of summaries from the data. The designs of observation sheets and tabulating cards were such that they should prove readily adaptable to other studies with only minor modifications.

REFERENCES

(1) Barnes, R. M., *Worst Sampling*, Second Edition, John Wiley and Sons, Inc. New York, 1957.

(2) Bryant, B. M., "Work Sampling in Maintenance," *Factory*, December, 1959, p. 72.

(3) Brisley, C. L., "8 Tips to Help You Save Time," *Factory*, December, 1958, p. 60.

(4) Connor, R. J., "Hospital Work Sampling with Associated Measures of Production," *Journal of Industrial Engineering*, March-April, 1961, pp. 105-107.

(5) Hansen, B. L., *Work Sampling for Modern Management*, Prentice-Hall, Englewood Cliffs, New Jersey, 1960.

(6) Heiland, R. E., and Richardson, W. J., *Work Sampling*, McGraw-Hill Book Company, New York, 1957.

(7) Isherwood, J. D., "Labor Cost Analysis by Work Sampling in the Small Business," *Journal of Industrial Engineering*, September-October, 1960, pp. 417-420.

(8) Morrow, R. L. *Motion Economy and Work Measurement*, Second Edition, Ronald Press Company, New York, 1957.

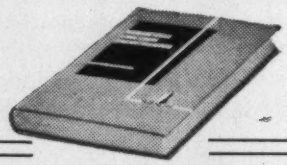
(9) Page, R. N., "Now—Easy Way to Sample Work," *Factory*, September, 1958, pp. 178-180.

(10) Reul, R. T. and Richardson, W. J., "Work Sampling, Key to Reducing Cost of Material Handling Activities," *Modern Materials Handling*, April, 1959, p. 88.

(11) Ritchey, J. A., "An Unusual Work Sampling Application," *Journal of Industrial Engineering*, November-December, 1959, pp. 450-455.

(12) Torgersen, P. E., "An Example of Work Sampling in the Hospital," *Journal of Industrial Engineering*, May-June, 1959, pp. 197-202.

(13) Wolf, M., and Riordan, D. P., "Work Sampling in an Engineering Design Department," *Journal of Industrial Engineering*, May-June, 1961, pp. 175-181.



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Wage Incentives and Human Relations

by **DALE S. BEACH**

Assistant Professor, Department of Management Engineering, Rensselaer Polytechnic Institute

OF THE 11.2 million production and related workers employed in manufacturing in the United States, 27 percent are paid on an incentive basis. There is great variation from one industry to another. For example the percentage of employees paid by an incentive arrangement in blast furnaces, steel mills, and rolling mills is 60, in knitting mills 64, in men's and boy's furnishings and work clothing 71, while at the low end of the scale we find 1 percent in commercial printing, 5 percent in sawmills and planing mills, and only 4 percent in aircraft and parts (3).

Those involved in Industrial Engineering and production management are well aware of the benefits which can be derived from a smoothly operating wage incentive program. Of prime concern to management, of course, is the increase in productivity (that is output per man hour) that can accrue. This means lower unit direct labor costs and usually lower unit total costs for each item produced. A second major gain for management is the powerful tool it acquires for regulation of costs through clearly established production standards. If these standards are determined by means of engineered work measurement techniques (as they should be), this is all to the good. Production planning and control is facilitated through the utilization of these production standards. And of course a major benefit for employees is that weekly take home wages tend to be substantially higher under an incentive program than under a daywork wage structure. Practitioners in Industrial Engineering have long recommended, that in order to provide sufficient motivation to work at incentive pace employees should be able, on the average, to earn 20-30 percent more than they could on a daywork job of comparable skill and effort. It should be noted that this rise in take-home pay can be achieved without increasing the unit labor costs to the company. Another advantage which some claim comes about from the introduction of an incentive system is the engendering of greater personal initiative and interest in their work on the part of the employees with a consequent decrease in the need for pressure on the part of supervision to achieve high production.

All of the foregoing is generally understood by professional engineers and managers in industry. However, inadequate study and concern have been given to the administrative and human problems associated with the operation of wage incentive systems. Professional practitioners, by reason of their education and training, have tended to seek continual refinements and improvements in the techniques of time study, predetermined elemental time systems, and work sampling while ignoring the equally important human relations problems attendant to wage incentive programs. It is perhaps because these human problems are so baffling and because their training has not equipped them with the analytical tools to successfuly cope with them, that Industrial Engineers have done little toward solving such problems as restriction of output, intergroup conflicts, bringing the whole man into the incentive program instead of just his body, equitable distribution of rewards for employee initiated ideas and many others.

Human relations problems have caused many a technically sound incentive system to founder. The author was once employed in a large industrial plant where extreme conflict between union and management over the administration of the incentive system caused it to be abandoned permanently. The plant reverted to daywork completely. In 1955 nearly one-fourth of all the grievance cases handled by the American Arbitration Association were caused by disputes over job standards, wage incentives, and time studies. During the period 1951-1956, more than 25 percent of all man hours lost from work stoppages were caused by disputes over work loads and work measurement (6). Let us now turn to an examination of the human relations problems which often result from the operation of a work measurement and wage incentive system in a factory. Certain of these can be most vividly portrayed by reference to an actual case example.

THE METAL APPLIANCE COMPANY[1]

Located in a large midwestern city, the Metal Appliance Company manufactures a variety of small household metal products and appliances such as can openers, knife sharpeners, graters, strainers, beaters, timers, aluminum ware, etc. Its manufacturing facilities are concentrated in a large multi-storied building in the industrial heart of the city. Total employment is about 3500. The production standards and wage incentive program are administered by an Industrial Engineering Department which employs 10 engineers. The production and maintenance employees are represented by a local independent union which is well established and has been the bargaining agent for 20 years.

A unique feature in this company consists of the procedure for adjusting disputes over time standards. The

[1] The name and certain information about this company have been altered to prevent identification. However, the facts regarding the wage incentive program are true.

company employs three union time study stewards who are members of the union, former shop employees, and who have been trained thoroughly in the system of motion and time study used by the company. When a worker feels that the production standard for his job is unfair (production standards are generally expressed in units per hour), he notifies his departmental shop steward. A written request for the services of the union time study steward is made out. It should be noted that the complaint is not called a grievance at this stage. The union time study steward would then investigate, make his own time study, compare the standard with similar previously accepted standards, and discuss his findings with the Industral Engineer assigned to that department. If the Industrial Engineer felt it was necessary, he might retime the operation himself. When the Industrial Engineering Department, the union time study steward, and the departmental shop steward reached agreement the matter would be settled. If no agreement could be reached, the matter could be appealed by the union to higher management and eventually to arbitration.

THE INDUSTRIAL ENGINEER, EMPLOYEES, AND MANAGEMENT

Employees at the Metal Appliance Company generally had ambivalent feelings about the Industrial Engineer. On the one hand they were eager to have him establish a rate on their jobs because this meant they would then have the opportunity to earn an incentive bonus which generally meant 25 to 30 percent greater earnings. If a job were allowed to ride for several weeks with no rate established, the employees became very upset because under these circumstances they merely received a basic hourly (daywork) rate of pay for their efforts. On the other hand the actual process of timing an operation frequently constituted a battle of wits between the engineer and the employee. The workers would try to obtain as favorable a rate as possible. They figured that if they could make the operation look harder than it really was, they could "fool" the engineer. This was called "giving him the business." Frequently it involved introducing extra and unnecessary hand motions. Of course the experienced engineer was aware of such attempts at deception and tried not to be taken in. If a particular rate turned out to be "tight" or unfair in the employees' eyes, then not only did they criticize the engineer but also the employee, on whom the original time study was made, was in the doghouse. The other workers generally charged that he had worked too hard and fast—therefore a tight rate resulted.

But, in addition to the above, the very nature of the relationship between the Industrial Engineer and the production employee was such as to produce tension and even animosity. Before timing a job, the engineer would conduct a detailed motion analysis in the hopes of uncovering flaws, inefficiencies, and waste motions. He would instruct the employee precisely how to move his hands and arms, how to position parts, and to use two hands simultaneously. The process of conducting the motion study plus the time study would involve anywhere from one to three hours of detailed observation and close guidance of the employee. Many of them resented being stood-over so closely.

One punch press operator blew up in anger one day at the engineer. He said, "Everytime I see any of you time study guys, I get so mad I see red."

For his part, the Industrial Engineer at the Metal Appliance Company often felt himself caught in the middle. He was expected by management to establish as many time standards on all new or changed operations as possible in his assigned territory plus insure that these rates were correct (that is, not loose). He was thus an instrument for controlling labor costs and achieving high production. On the other hand he had to live with the workers and the union. Continued antagonism only made his job that much more difficult. So he experienced strong upward pressure for generous time standards from the workers and strong downward pressure from management to hold down labor costs and set as many standards as possible to get out the production.

FLUCTUATION OF EARNINGS

In order to maintain a stable standard of living, employees must be able to depend upon a fixed paycheck from week to week. For hourly paid dayworkers and for salaried employees this is an accepted thing. For incentive workers this condition seldom exists. One week they may work on an operation on which they can readily earn a substantial bonus, while the next week they may be assigned to an operation having a "tight" standard. The practice by which employees save up their work tickets from days of "good" production and turn them in on days when their actual output is low as a means of stabilizing their earnings is widespread in industry. Or they may have to work on an operation for which no rate has been set. At the Metal Appliance Company, incentive employees in this situation were paid only their guaranteed base rate. On the other hand some organizations feel it desirable to remove this source of employee discontent by paying an hourly rate equivalent to the incentive earnings which the employee has established previously as his average.

Earnings fluctuations are also caused by machine breakdowns, variations in the quality of the materials, changes in employee skill and effort from day to day because of physical state and moods, and many other factors. Companies have evolved a variety of ways to handle these problems. Some pay average incentive earnings if the cause of the delay is management's and they pay the guaranteed base rate if the cause is due to the employee. Others pay only the base rate for all delays and "down" time. But the point being emphasized here is that all the foregoing conditions tend to create administrative problems and serious human relations difficulties.

WAGE INEQUITIES

In a large electronics manufacturing plant a few years ago, the skilled machine shop employees (many of whom had gone through an apprenticeship program to qualify as journeymen) who were paid daywork rates went on a sit-down strike because the essentially unskilled and semi-skilled women assemblers on incentive were earning more money than they were. To assert that the pace at which an incentive employee performs is substantially greater than that of the daywork employee generally does not placate the latter. He wants more money.

Some companies attempt to satisfy maintenance, service, and inspection employees who are on daywork by raising their hourly rates of pay above the base rates for incentive workers. This is accomplished at the bargaining table with the union or, if there is no union, at a time when the whole wage structure is re-adjusted. The net effect is to narrow the gap between the take home pay of incentive workers and that of dayworkers who are in comparable labor grades. This may mean that the incentive worker makes only 10-15 percent more than he would if he were on daywork. Such an arrangement is not a solution at all since it doesn't get at the core of the problem. A more sensible approach is to place all daywork employees on incentive. Many companies have attempted to do just this. However the work measurement and administrative problems are much more complex and the results do not always justify the time, cost and effort involved.

A more startling type of wage inequity may occur among incentive employees themselves. This can come about when unskilled workers on incentive jobs have higher take home earnings than do skilled workers on incentive. William Gomberg tells of the garment factory in which floor girls being unskilled had the lowest base rates while lockstitch operators whose work was skilled had the highest base rates. However total incentive earnings of the floor girls were 50 percent greater than those of the lockstitch operators (2).

Bitter animosities sometimes develop between work groups having low earnings potential and those having very high piecework earnings. This can be a serious problem for management. A team of girls on a spray painting operation in one toy manufacturing firm had greatly increased their bonus earnings through being given control over the speed of their own conveyor line plus certain changes in working conditions. This caused resentment by other work groups and scheduling difficulties for management. The problem reached such a state that management actually took the step of changing the operation such that productivity was reduced (5).

RESTRICTION OF OUTPUT

In installing a wage incentive system, management makes the underlying assumption that wage earners will work as hard as they can in order to maximize their earnings. Indeed some workers respond in just this way. They feel that hard work and the giving of a good, honest day's work to the employer is a major virtue. They are strongly motivated for financial gain. Money is often an end in itself. Hard work, self denial of too many worldly and social pleasures, thrift, and the acquisition of more and more money are characteristics described so well by Max Weber, the German historian and sociologist, in his well-known book (4).

However, many workers do not respond in this way. They want more money, yes; but not at a sacrifice to other values in life. They are not motivated primarily by competition but rather seek the cooperation, friendship, and esteem of their fellow workers. Loyalty to one's friends is important to them. They want to belong and be accepted by the group. Thus many times employees will consciously restrict their production below limits imposed by fatigue because of social motives. To have time to talk and socialize during the work day is important to them. To go home at the end of the working day with plenty of energy left to have a good night's bowling with the team or to spend an evening at the fraternal lodge makes life worth living.

Many times workers feel that unrestrained production by a few individuals is the quickest and surest way to bring out the Industrial Engineer for a re-examination of the job. Sure, management promises there will be no unjustified rate-cutting. However work methods can always be improved. If the methods or workplace layout are altered, management has a perfect right to restudy the job and set a new rate. Of course, incentive employees feel that it is always jobs with high earnings that are restudied. Employees tend to believe that if they all produce about the same percentage above standard, then none of them will stand out in management's eyes and nothing will happen.

Fear of rate cutting apparently is ingrained in workers. It is almost part of the working man's culture. In the Metal Appliance Company, for example, the employees were always suspicious of management's motives in this respect. If a new part, having a new part number, but looking very similar to an old part, were introduced into the production process the union stewards and the employees were always apprehensive lest the new rate be "tighter" than the old rate. If it should be a tighter standard, they would charge that the new part was deliberately introduced to eliminate a "loose" standard on an old part. Management tried to minimize employee discontent in this company by always using the old, accepted rate if the time standard for the new part was within 5 percent of the former.

Some field researchers have noted a definite social cleavage and conflict between those employees who are "rate-busters" and those who are output "restrictors." Frequently the individualistic, "rate-busters" are ostracized from the group. It is felt they destroy group security and solidarity. Collins, Dalton, and Roy, found in the

factories they had studied definite correlations between employees' rates of production and their ethnic background, political beliefs, union affiliation, and degree of social participation (1).

On individual operations employees often deliberately restrict output to prove to management that a work standard is unfair. This is a powerful weapon in their hands if the company is sorely in need of the production. One example from the Metal Appliance Company will serve to illustrate the point. A particular punch press operation had been in dispute for several weeks. The standard called for 700 pieces per hour. The employees claimed this rate was impossible. To prove it all three shifts on this operation kept production down around 500 per hour. The low production rate pinched management on deliveries to its customers. The job was re-studied, the Industrial Engineering Department admitted an error in the initial standard, and a new rate of 630 pieces per hour was set. This evidently satisfied the employees because they then proceeded to produce at a rate of 750-800 to earn their customary incentive bonus.

INCENTIVES ARE FOR WORKERS' HANDS— NOT THEIR MINDS

Ever since the days of Frederick W. Taylor, when he advocated an organizational separation of planning from doing, the workers have been relegated to the doers while Industrial Engineers and managers have been the thinkers and the planners. The fact is that conventional wage incentive installations reward wage earners only for exerting greater physical skill and effort. The plans themselves do not motivate people to figure out a better way to do the work, to exercise their design or inventive powers. In fact, most incentive programs penalize the man who designs a better method. If a worker designs and builds a new jig or other device to increase his earnings on the job, then management says the method has been changed. This justifies a new time study and a lower piece rate or time standard. So his earnings drop down to where they were before and the worker feels his idea has been expropriated by the company.

The solution, some say, is for the worker to submit his idea to management under a formal suggestion system. Then he will be eligible to receive a monetary award if the suggestion is adopted. But to the worker this is no solution at all because the conventional suggestion plan pays out only 10 percent of the first year's net dollar savings. It doesn't take the worker long to figure out that he would make more money through increased incentive earnings on the job if he were able to devise and build his own jigs and work place aids and keep them secret from management. Indeed many employees in shops around the country do just that.

OVERCOMING THE HUMAN PROBLEMS OF INCENTIVES

There exist no easy solutions to the difficulties which beset conventional wage incentive installations. The quest for greater accuracy of work standards has led to continual efforts to refine time study techniques, to conduct research in predetermined elemental time systems, and to pursue work sampling methods with mounting vigor. There is still the cherished hope that if the true standard times for the accomplishment of work elements can be discovered, then controversy among employees, unions, engineers, and managers will cease. The never-ending quest for improvement in work standardization techniques is desirable but unhealthy because it is one sided. The vast majority of problems in the work measurement and wage incentive fields are assuredly human not technical. Engineers have dwelt on the technical because that is their forte. But even the best of techniques can be wasted through improper application and administration. Very probably the work measurement techniques now available are as accurate as they will ever become and as accurate as are really necessary. The inherent and great variability of human beings combined with the fact that selection of employees who fit the requirement of the "average worker" is itself a question of probabilities, makes the search for a universal standard of a fair day's work elusive.

The emphasis must be shifted. The famous Hawthorne Researchers of a generation ago demonstrated to us that the way employees feel about their work, the treatment they receive from management, and their internal group spirit are major determinants of the level of output. Much exciting research has been going on in recent years in the fields of organizational behavior, group dynamics, leadership, employee motivation and morale—in short, in the broad field of industrial human relations. What is needed is a melding of the contributions which the engineering profession has been making with the knowledge and insights which the behavioral scientists are making available. Engineers need greater education and training in the behavioral sciences, both from a theoretical and applied standpoint, so that they can institute not only mechanically correct incentive programs but ones which will encompass the total work environment system.

Incentive programs must be designed so that they stimulate and reward employees for their ideas, not just for their physical effort. Employees must know and believe that it is the whole man which the employer seeks to motivate. Initiative and ingenuity must be rewarded. These new programs must take advantage of the contributions people can make through combining their ideas and energies.

While anticipation of monetary gain constitutes a major incentive for many people, human motivation is not unidimensional. People strive also for the esteem of others, for higher status. They seek ego enhancing satisfactions, such as opportunities for self-expression and a sense of achievement. They crave a sense of identification with something or someone and a feeling of belonging. Respect, dignity, and a sense of personal worth are other

common drives. Thus a true incentive program should endeavor to meet other needs besides financial.

A fruitful approach lies in creating programs which include some form of employee participation in decision making. While it is the function of management to determine organizational goals and to set policy, employees can make worthwhile contributions in the "how" part of the work. With proper leadership, they can propose new ideas for improving their jobs and the work situation in general. They have intimate familiarity with this aspect of a business. Forms and devices for this are many. Experimentation will develop the method most suitable to a particular organization. They may take the form of labor-management productivity committees, suggestion committees, "junior boards of directors," foremen-employee departmental conferences, shop committee meetings and the like. Group, departmental, or plant-wide incentive programs can therefore reward employees for cooperation in solving production problems. Such participation programs can develop greater employee interest in the success of the enterprise.

Some companies, recognizing the human and administrative problems inherent in the conventional wage incentive program, have installed a measured daywork system. While there are a number of variations of the measured daywork approach, the essential features are:

1. The establishment of a work standard for every operation.
2. The absence of a direct monetary incentive.

An employee is paid the hourly wage rate determined for his job by job evaluation and he is expected to meet the production standard which has been set by one of the accepted work measurement techniques. The company gains the benefit of production standards for purposes of control of labor costs, production planning, and performance evaluation. Employee earnings do not fluctuate week to week. In some measured daywork installations the hourly rates of pay are adjusted every few months in accordance with the employees' performance and merit during that period. The proponents of measured daywork feel that it retains the advantages of a straight incentive plan while avoiding many of the pitfalls. Since an analysis of the full implications of measured daywork would require a separate and lengthy treatment, this article is limited to an evaluation of conventional wage incentives.

The way in which employees feel about their work situation accounts in large measure for their willingness to produce, and it is significant that where their elected union leadership favors the wage incentive method of payment such programs flourish. Witness the women's wearing apparel industry where the International Ladies Garment Workers Union fully supports piecework and where 71 percent of all workers are paid in this way. In this industry, made up of many small employers, the union participates actively in the time study and rate setting process. The employees feel that they have a voice in establishing piece rates. By contrast the low percentage (thirteen) of the labor force in the automobile industry on incentives is due in no small measure to the long-time hostility of the United Automobile Workers Union. The point being made here is that a positive form of employee participation and ego-involvement in the operation of incentive programs is an ingredient necessary to success. People tend to support those things which they have had a part in creating and controlling. The functions of planning and doing, separated by Frederick Taylor fifty years ago, must be re-combined to include the whole man. The potentials of employees' minds must be tapped as well as their bodies.

REFERENCES

(1) Collins, Orvis, Dalton, M., and Roy, D., "Restriction of Output and Social Cleavage in Industry," *Applied Anthropology* (Now *Human Organization*), Vol. 5, No. 3, (Summer 1946), pp. 1-14.

(2) Gomberg, William, "Union Interest in Engineering Techniques," *Harvard Business Review*, Vol. 24 (Spring 1946), pp. 356-365.

(3) Lewis, Earl, "Extent of Incentive Pay in Manufacturing," *Monthly Labor Review*, Vol. 83, No. 5, May, 1960, pp. 460-461.

(4) Weber, Max, *The Protestant Ethic and the Spirit of Capitalism*, Charles Scribner's Sons, New York, 1930.

(5) Whyte, W. T., *Money and Motivation*, Harper and Brothers, New York, pp. 90-96.

(6) *Time*, March 26, 1956, p. 94.

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READER COMMENTS

METHODS USED IN SOVIET RUSSIA TO INCREASE PRODUCTIVITY

Some time ago, the Kowalyow Method for exchanging information about operational experiences between industrial enterprises was established throughout most of the Soviet Union and the countries of the Eastern block.

For many industrial operations in these countries, the same methods and time standards are in force. Should an engineer or an individual worker develop a more efficient method, a description of the new method is communicated to all enterprises making the same or similar products. This method was suggested by Kowalyow and has been highly developed, especially the standardized system of analyzing and describing the elements of the operations. Excellent results have been reported from the ball bearing manufacturers and also from many other industries.

The Mitrofanow Method has been developed more recently and uses the following aproach:

An Industrial or Production Engineer examines all the drawings of items to be produced and sorts them according to their shape or form. He groups together all kinds of rings, bushings, bolts, rods, levers, wheels, gears, etc. While the function of the parts may be a guide in this work, their similarity is the deciding factor in the kind of classification.

In this kind of grouping:

1. The same tools, jigs, fixtures, gauges and even special single purpose machines may be used in the production of all these parts.
2. Various similar parts may be manufactured in one setup with only minor adjustments.

Both these circumstances contribute to the economy and efficiency of production.

From the drawings of these parts, a new, synthetic, complex or master part is developed which contains the important features of all these parts and serves as a basis for the tooling and production engineering of the whole group of parts. This system, developed by the Russian scientist, Mitrofanow, is sometime called group manufacturing.

This method was developed in the production of heavy machinery in small quantities and has been used mostly in lathe operations, but may be applied also to drilling, boring, milling and other operations. Occasionally it is used in mass production, such as the electric, optical and instrument industry of the USSR and neighboring countries.

This approach to production problems often results in a chain reaction of numerous other useful questions, such as: When are two parts alike? What kind of differences are important? Which differences matter little or not at all when a whole family of parts is going to be produced? How is the production control department to schedule the parts of different production orders? Will a new number system be helpful? Will the inventory go up too high? It is evident that the whole field of standardization may be influenced by a study such as this.

As with many new principles, it is necessary to get the cooperation of numerous departments affected by such an innovation, and there also exists the danger that the designers, for the sake of making parts as much alike as possible, will neglect the basic purpose and function which the part is to perform. Nevertheless, the Mitrofanow method has a strong impact and fruitful effect on the design and production in industry.

A competitive and nontotalitarian economy has only limited chances in the application of the Kowalyow method while the Mitrofanow method can be used by many enterprises within their own area, and it has proved especially useful in industries producing in small quantities, in job shops, generally in the production of producer goods, a sector which has always been a problem child as far as modern production methods and productivity are concerned.—*Manfred Knayer, Stuttgart W, Roeckenwiesenstr 10, Germany.*

HOSPITAL WORK SAMPLING WITH ASSOCIATED MEASURES OF PRODUCTION, by Robert J. Connor, *Journal of Industrial Engineering,* March-April, 1961.

In the last paragraph, first column, page 107, the author states, "This result is of some interest for it means that nursing personnel give a standard level of care regardless of how much care is to be given and how many hours are available." The author appears to be defining "care" in terms of the number of hours devoted to an activity presumed to be related to patient care. Since the efficiency in applying nursing effort is unknown and since there is no assurance that nursing time produces effective care, it does not appear to be reasonable to draw conclusions regarding the amount of care or the level of care achieved. Obviously the author's reference to a "standard level of care regardless of how much care is to be given," relates to nursing time, not amount or kind of care provided.

In the second paragraph, second column, page 107, the author states, "Hence, if labor-saving devices are introduced the personal time saved will not go into direct care but into non-productive activity. The conclusion is that in order to benefit from labor-saving equipment and procedures they must be introduced so that the number of nursing personnel can be reduced simultaneously." It is not clear whether this conclusion applies to labor-saving devices generally and to hospital situations generally or to the particular behavior in the author's study situation. If he means to describe what happened in his experiment, one cannot quarrel with his findings. However, the study does not appear to consider other relevant variables, for example, effectiveness of supervision, which might be more influential than the variables studied in determining or influencing how time saved is re-allocated in any particular situation.—*Harold E. Smalley, Professor, School of Industrial Engineering, Georgia Institute of Technology.*

AUTHOR'S COMMENTS

Thank you for the opportunity to reply to Professor Smalley's comments on my article. His comments indicate that he has read and understood the article. His objections to the conclusions drawn on "care" and "labor-saving devices" are quite understandable.

With regard to the comments on "care" and "nursing time" the problem is simple. I have used "nursing time with patients" as a measure of the amount of direct patient care given (as direct patient care was defined in the article). Professor Smalley, apparently, believes this is incorrect. I can agree that "nursing time" is not an ideal measure, however, no better measure exists, and I believe this measure is valid. The fact that nursing time was used as a measure of the amount of direct patient care was mentioned in the article.

Before responding to the comments on "labor-saving devices" let me point out a small typographical error. In the second paragraph, second column, page 107, the sentence starting, "Hence, if labor-saving devices . . ." has an incorrect word. It should read, "Hence, if labor-saving devices are introduced the *personnel* time saved. . . ."

In reply to Professor Smalley's comments on the conclusion

regarding labor-saving devices two points should be mentioned. First, the conclusion, as all others of the study, is meant to apply to the units studied. The only general conclusions are made in the last paragraph of the article.

Second, Professor Smalley raises the question of the re-allocation of time saved. It is undoubtedly true that if the time saved could be put to "good use" this would be another way of benefiting from the introduction of labor-saving devices. In the study situation, however, the time saved was not being put to good use. Therefore, it was concluded that under these conditions the only way to benefit from the introduction of labor-saving devices would be to reduce the number of personnel. Another way of saying this is that in the study variables, such as "effectiveness of supervision," were considered as constraints and not as variables subject to control.—*Robert J. Connor, Assistant Professor, The Johns Hopkins University.*

THE METAMORPHOSIS OF INDUSTRIAL ENGINEERING INTO MANAGEMENT ENGINEERING—PLEA FOR CHANGE IN NAME by Joseph D. Carrabino, *Journal of Industrial Engineering*, January-February, 1961.

Dr. Joseph Carrabino is to be commended for his very thought-provoking article. Although I agree with him that there is need to upgrade the Industrial Engineering profession, I can't see how the mere changing of the name of "Industrial Engineering" to "Management Engineering" is going to solve the problem. The basic weaknesses underlying our profession cannot be cured by such a simple remedy.

Throughout his discussion, it seems to me as though Dr. Carrabino has completely overlooked a fundamental point. That is, are Industrial Engineers to continue to be "engineers" and is the American Institute of Industrial Engineers to continue to be an "engineering society"? If the American Institute of Industrial Engineers (or whatever its future name might be) is not to continue to be a truly engineering society, then it should cease to pretend to be, should remove the word "engineers" from its title, and should gracefully withdraw from its proposed space in the new United Engineering Building. It is my firm conviction that if Industrial Engineers are going to continue to carry the label "engineer," then they should be engineers in every sense of the word. And I hasten to add that making a business administration graduate proficient in mathematics will not make him any more of an engineer than is a mathematician, a physicist, or a chemist.

If we were to adopt the proposed title of "American Institute of Management Engineers" and continue to remain an engineering society, it seems to me as though we would be undoing much of the good that has been achieved in our profession in recent years. Through the excellent work of the American Institute of Industrial Engineers and the approximately 50 accredited educational programs in Industrial Engineering, great progress is being made in elevating the status of Industrial Engineering. It may be anticipated that this progress will continue at an accelerated pace, and I question if we should do anything that might interfere with it.

It appears to me that the "New American Institute of Industrial Engineers" that Dr. Carrabino is proposing would be little different from the present Society for the Advancement of Management or several other general management societies. It could not possibly have any membership qualifications that could be thought of as having a sound professional basis. One of the reasons that such organizations as the American Medical Association and the American Bar Association have gained such great strength is because of the fact that they have strong professional requirements for membership. On the other hand, even with the present professional requirements for membership in the American Institute of Industrial Engineers, there is the continuous problem of some people maintaining short-lived membership. One of the reasons that these people probably tend to shed their Industrial Engineering badges so easily is because they pick them up easily. They are interested in Industrial Engineering only so long as they are working in a department carrying the label "Industrial Engineering." We hope that the future will partially solve this problem and as more people graduate in Industrial Engineering, they will continue to think of themselves as Industrial Engineers no matter what positions they may be filling.

Based on frequent contact with Industrial Engineering curricula, it has been my observation that great improvement is taking place in our educational programs in Industrial Engineering. Our leading engineering institutions are doing a noteworthy job of changing their programs into strong engineering programs. Certainly, they are not the "soft programs" that existed a few years ago.

It occurs to me that one of the weaknesses of our profession that Dr. Carrabino might have touched upon is the fact that so many groups in industry carry the title of Industrial Engineering Department. Thus, the connotation is that Industrial Engineering consists of the functions performed in that department. Since in many companies the principal activities performed in the Industrial Engineering Department only pertain to methods improvement and work measurement, these activities are continually associated with that department. Needless to say, methods improvement and work measurement are only two of the many functions performed by professional Industrial Engineering groups. Thus, there is real need for industry to take a fresh look at the titles of such departments and to give them more suitable titles.

I am in complete agreement with Dr. Carrabino that Industrial Engineers ought to be used in any of those areas in which they can make full use of their professional abilities. I would not restrict the use of the Industrial Engineer to any one department but allow him to be utilized wherever his professional training and abilities would enable him to do a creditable job. But I, again, would like to stress that he is an "engineer," and he should be used in those activities requiring him to perform a *design function*. If this utilization of his talents falls most frequently in the manufacturing phases of industrial operations, I can't see that this is anything about which to get alarmed. Is this any worse than having other engineers spend a lifetime of doing nothing but designing a product?

In closing, may I reemphasize that the Industrial Engineer is an *engineer*. There appears to be such a strong desire on the part of many people to make him a member of top management, that his primary function as a designer is frequently forgotten. This inevitably leads to failure to establish Industrial Engineering activities possessing sufficient vertical depth and discourages Industrial Engineers from wanting to spend their professional lifetimes in positions involving so little promotional opportunity and/or challenge.—*H. T. Amrine and Colleagues, Department of Industrial Engineering, Purdue University.*

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MANAGEMENT'S ENGINEER

Upon first reading of this article one may be inclined to join the author in urging the change he suggests. Salveson (2) in 1954 suggested that the Industrial Engineer was *Management's Engineer*. In the same paper he pointed out that the generic term "industry" is not synonymous with "manufacturing," but rather with "business" in its broad sense.

Certainly there is much merit in pooling efforts and resources with others so that overall results may be maximized. If this results in promoting our profession in the eyes of management and the public, improving the status of the member, plus other benefits, the change appears to be a most logical course of action.

More sober reflection points to the pitfalls of such an easy solu-

tion. For many years the Industrial Engineer has held to the position that he is an engineer first and an Industrial Engineer secondly. Engineering is basic, with the Industrial Engineering subjects built upon the engineering science and analysis courses. There has been much emphasis on the design phases of integrated production systems, their planning, installation, operation, and control. The competent Industrial Engineer was truly capable of contributing to these functions and, in time, to take the responsibility for exercising both the engineering and management judgments required in directing the project.

When an organization becomes too inclusive in its membership and reduces qualifications for membership to the point where "anyone with an interest in the field" may join, it loses its professional identity. Prior to the organization of the AIIE, Industrial Engineers looked to the Society for Advancement of Management as their professional society. Business students and Industrial Engineering students shared in the conduct of the student chapters. With the organization of the AIIE with its student chapters, the SAM on most college campuses was turned over to students of business administration. The students had little interest in a joint society when each group could have its own. The Industrial Engineer who was searching for a more rigorous methodology for solving his problems found little at the meetings or in the publications that helped. It remained for the AIIE to develop a publication that went beyond the description to more rigorous methods.

Mrs. Gilbreth said in a talk (1) before an AIIE meeting in 1952 that "because the Society for Advancement of Management also contains many members who are not engineers (and this is right, and we hope it will always continue to admit people who come from a variety of backgrounds and experience) it has become increasingly important—in fact, I think imperative—that there be a Society like this one that concerns itself primarily with the Industrial Engineering problems and where we can be perfectly sure we have a place, a magazine, and an organization where the problems which concern us so deeply can have 100% of the time, energy, and attention which we want to give them."

The criticism leveled at business school education has undoubtedly resulted in improved curricula at many schools but are they now producing "engineers"? There can be no doubt that the Industrial Engineer can expect competition from Business Management graduates for the management positions as well as the Industrial Engineering jobs in industry associated with measurement and controls. Who does the work will be determined by who is available and what his competence is. Many other types of engineers compete for these same Industrial Engineering and management positions and will continue to do so. Participation at the higher levels of management is earned after demonstrating the ability to make a contribution—not by assuming a name that implies the qualifications. Few college graduates in engineering at the bachelor of science level possess the competence in mathematics to make significant contributions to operations research without considerably more study in mathematics and statistics. This is especially true in situations where new mathematical models must be designed. The engineer with an interest in mathematics can acquire necessary competence in reasonable time because of his undergraduate background in mathematics. As a practicing Industrial Engineer, he can apply the newer tools obtained from mathematics where appropriate in solving problems at any level. Once he demonstrates his ability to use these effective tools, there is no longer a lack of opportunity to apply them.

There is a further problem of professional registration. Can anyone, who wishes to, call himself a "management *engineer*"? Today's management consultants have no problems of registration for practice in most, if not all, states. While many practicing management consultants are competent engineers, they depend on their record of successful work rather than a title including the word "engineer." Certainly we all have some idea of the wide range of qualifications presented by those practicing in the management consulting field. I agree with the author's quotation from Urwick that the engineering profession should not claim special competence in those fields to which the epithet "engineering" has been attached as a synonym for "scientific." The reverse is just as true. The nonengineer who has competence in a "scientific" area may not assume that this automatically entitles him to be called an "engineer." For this reason I object to the suggestion that graduates of business administration curricula are to be indistinguishable from engineers.

It seems to me that there is no need to regard education and practical experience in Industrial Engineering as a limitation to future growth and progress of the individual. Quite the contrary, with his education built on mathematics and basic science, engineering science and analysis, and the humanities, he finds it easy to extend the application of his knowledge to other fields—applied statistics, mathematical programming, and others. As we demonstrate our competence to solve more and more difficult problems, we build status and respect for the Industrial Engineer.

REFERENCES

(1) Gilbreth, Lillian M., "The Present and Future of Industrial Engineering," *Journal of Industrial Engineering*, November 1952, pp. 12-13.

(2) Salveson, M. E., "The New Look in Industrial Engineering," *Journal of Industrial Engineering*, November 1954.

—C. A. Anderson, Head, Department of Industrial Engineering, North Carolina State College.

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The arguments which Dr. Carrabino advances for changing the name of the professional society and presumably the job title of the practitioners in industry are not particularly impressive. In the first place, the society is made up of individual members whose abilities and potentials range from the member whose capacity is equal to simple standard setting to the member who is contributing complex mathematical models used in operations analysis. The capacity of this society and of these individuals is not likely to change with a change in name.

The choice of the word "metamorphosis" is somewhat unfortunate. It is not a word which would seem appropriate to evolutionary change in a species or to the ecological adaptation and interrelationships between the species in the enviroment. According to Webster, metamorphosis can mean "1. change of form, structure, or substance, especially by witchcraft or magic. Also, the form resulting from such change." The more familiar connotation of the word as used in zoology suggests drastic changes in form and function, such as the transition from chrysalis to butterfly. In spite of isolated examples to the contrary, it has been observed that students in engineering tend to carry with them the capacity for technical development which is proportional to that achieved in their formal education program. In other words, their future assimilation of technical mathematical material will depend primarily upon their previous achievement in the field of mathematics, etc. It would seem then that, if we are to have any substantial change through the change in name, it would come about as indicated by the first meaning of the word metamorphosis.

It would appear that the author has taken a description of management function and superimposed upon this the contributions of Industrial Engineering, the potential of the controller, and the purposes an objectives in operations research which he then seeks to synthesize into a new organization structure to be established by management. In effect, he would superimpose on a functional organization chart a new functional area to be known as Management Engineering which would have branches

or groups associated with each functional area as well as with top-level management. One can only vaguely imagine how this would be undertaken. It might be that such an organization structure would be appropriate for the top one hundred corporations in the nation. One would not quarrel with his proposal for management to establish this type of organization in the corporation by any name, including Management Engineering. Unfortunately, the author's plea which follows immediately is for a change in the name of the American Institute of Industrial Engineers. I am under the impression that it really does not make very much difference by which name we are known. In the final analysis the performance of those who operate under the label will determine the meaning of the label to those who are concerned with it. To illustrate the point, one needs but to point out that it is not possible to tell very much about a group operating under the label operations research, systems science, or management science unless additional information is given. The author argues that the Industrial Engineer would be subservient to the operations researcher and the management scientist. In the long run, the relationship between Industrial Engineers, operations researchers, systems scientists, systems researchers, or management scientists will be determined by the capacities and/or abilities of the various practitioners operating under the label.

The author seems to be guilty of the behavior which he attributes to the Industrial Engineers who adopt the name to suit the occasion. The chameleonic behavior is a surface phenomenon which does not change the essential features (either form or function) of the organism. Likewise, the adoption of a name by the American Institute of Industrial Engineers would not change the essential features of the society or its mission or the capacity of its membership. We cannot support Dr. Carrabino's plea for a change in the name of the American Institute of Industrial Engineers but we can take note of the section "Trends in University Schools of Engineering and Business Administration."

He makes several interesting observations. We would be forced to agree that there are business administration schools that are moving in the direction of more quantitative approaches to subject matter. It is but a trend, however, since most schools have made very little significant advance in this direction. It is also true that engineering colleges generally are moving in the direction of more physical science curricula. Industrial Engineering curricula are incorporating more mathematics (subject matter not required in other engineering programs) and building less on the so-called engineering-science courses in their Industrial Engineering course structure. As the traditional boundaries in engineering colleges are broken down and the curriculum tends to a more uniform applied physical science program, there is serious doubt whether the Industrial Engineering program will find haven in the engineering college. Many Industrial Engineering educators, finding that they have their own subject matter courses of an engineering-science nature and a great need for more mathematics have sacrificed the traditional engineering-science courses in engineering mechanics, thermodynamics, etc., to the point where there is serious question under current accreditation policy as to whether or not they belong in engineering. Admittedly, Industrial Engineering Departments have had a difficult time justifying their existence in colleges of engineering in times past and have had to compete with the other departments for the better student, often coming out second best in this competition. If the present trends continue, it is expected that these disadvantages will continue to be highly significant. The day may soon come when more engineering colleges will drop the undergraduate portion of the Industrial Engineering program as presently set up. It is clear that most of the functions now performed in the engineering college by the Industrial Engineering program could be undertaken in a business administration program. It is not likely that the college of engineering would look with favor upon a department of management engineering in the college of commerce, but it really would not make a great difference what name was used to describe the quantitative approach sugggested under the various titles: management science, operations research, etc.

The question of a change in name is a trivial question for those in the academic area in light of the other questions raised by significant trends in engineering education. If engineering educational programs continue to move in the direction of a few basic areas of applied science (materials science, applied physics, etc.) with the primary emphasis being on physical science, then the Industrial Engineering educator must find a mission and a program which is compatible with the mission of the engineering college or find a new base of operation. It is quite conceivable that an undergraduate Industrial Engineering program would be lost altogether in those engineering colleges moving to the extreme science program for undergraduates. It is obvious that these concerns are largely independent of a change in name and it would appear that the plea for a change in name is really a red herring used to provoke consideration of goals and objectives for the profession.—*David F. Baker, Department of Industrial Engineering, Ohio State University.*

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WHAT'S IN A NAME?

This, I believe, is the kind of contribution that must be valued in terms of the total response it produces and not by a tally of yeahs and nays. Professor Carrabino is so thoughtfully and agreeably provocative that he would not be properly honored without an expression of disagreement. It is in this spirit, as well as on personal belief, that I dispute the need for discarding our identification as Industrial Engineers.

There is, of course, no doubt that the character of Industrial Engineering has changed markedly over the past decade. It would be disturbing indeed if the profession had been unable to respond to the need for change. At the same time, when I consider what has been happening in the rest of engineering during this period it does not seem that we are unique in the experience of change. Professional groups, no less than individuals, must have the capacity of adaptive behavior if they are to remain socially useful and thus survive. Is it not sufficient that we are modifying the character of Industrial Engineering to maintain and if possible increase the utility of our contributions? Or is it proposed that we can improve the effectiveness of our adaptive behavior simply by changing our name?

I do find a suggestion in Carrabino's argument that this development might somehow go along better if it were carried out in business schools, but this may be a mistaken impression for I can't pin down the reasoning. I suppose that if business schools did want to bring Industrial Engineering into the fold, people might feel more comfortable all around if the name were first changed to management engineering. Here at least is one reason, albeit a political one. The other reasons are not clear to me. I am aware of the fact that Industrial Engineering developed in the engineering schools during a period in which it was predominantly concerned with the utilization of labor resources. I can also see that the utilization of technology is becoming an increasingly dominant factor in the economics of productive activities, and have felt that this circumstance implied increased interactions between industrial and the other branches of engineering. If I correctly understand Carrabino, however, this is just not so. I think he's mistaken, but I am probably overestimating the importance of the issue if, as he says, "business administration schools are rapidly taking on the characteristics of engineering schools."

One might take a narrow view of this development and suggest that business schools should become as engineering—like as they like, so long as they stick to their business. A broader view would

interpret this development as a drawing together and visualize a reduction in educational overhead by the combination of business and engineering under a single Dean. I personally think this would make a great deal of sense since an increasing number of engineers are rising to management positions, whereas businessmen in general are dealing with an increasingly technical world. However, Parkinson's Law is inhospitable to this solution and if Carrabino sees "a line drawing sharper each day," I suspect someone is doing it to make sure the law works.

But whether business and engineering schools retain essentially different characters and remain separate, or develop similar characters and become ever more separate—or, alternatively, merge—I'm not persuaded that the issue has a strong bearing on changing the name of Industrial Engineering.[1]

An argument can perhaps be made for changing the name of a profession if its character has changed so radically as to render the old name unsuitable. This argument seems a part of the support for Professor Carrabino's plea since he speaks of a "break with the restrictive word 'industrial' with all its manufacturing connotations." In my opinion, however, he has neglected some of the semantic facts of life. The original descriptive meanings of the separate parts of a name have no necessary connection with what is currently designated by those words used as a name. I, for example, am not really David's son; nor, insofar as I know, is the author with whom I'm now taking issue really a carrabino.[2] In fairness, I must grant that these facts seem to be at least partially acknowledged, for the author speaks elsewhere of the "Industrial Engineer badge." Nevertheless, I sense that he is viewing the badge as it was minted circa 1935-1945; or is, at least, asserting that the rest of the world generally does so. If this be true, my own experience is both fortunate and exceptional for I find that the 1961 minting of the Industrial Engineering badge is supplanting the tarnished pre-war issue with encouraging rapidity.

I propose, therefore, that it is both possible and necessary for the Industrial Engineer to experience professional growth in the acquisition of new techniques and the response to new opportunities. I say further that this growth is occurring and that the world is at least beginning to see an Industrial Engineering badge that looks a great deal different than the 1935-45 mintage. It seems to me, then, that the author's "alchemy" is somewhat behind times when he proposes the reaction:

"Controllership Function + Industrial Engineering + Operations Research = *Management Engineering*"

I would call to his attention the fact that with moderate pressure and in the presence of light, the following reaction is consistently obtained in pilot plant operations and is probably feasible on a production basis:

$$IE^{\infty} + OR = IE^{\infty}.$$

Insofar as I can judge, the IE^{∞} isotope has very superior properties.

There has also been some experience in mixing the IE^{∞} isotope with the controllership function,[3] in accordance with the Carrabino formula. We have found this mixture to be an effective solvent for a number of problems but have yet to find that the initial ingredients are metamorphosized into an entirely new substance.

Admittedly, our experiments have been conducted at moderate temperatures and pressures with gentle agitation since we find these conditions best for producing the desired solvent characteristics. It is entirely possible that at high temperatures and pressures and with more violent agitation (which could possibly be introduced by high energy acoustic techniques) the Carrabino reaction could be accomplished. An alternative explanation of our failure to obtain the metamorphosis hypothesized by the Carrabino reaction is suggested by Webster's first-listed definition of metamorphosis: "Change of form, structure, or substance, especially by witchcraft or magic . . ."—*Harold O. Davidson, Vice President, Industrial Engineering, Operations Research Incorporated.*

[1] If I have taken the author's argument somewhat off its tracks, I apologize but plead in defense that he laid them with loose joints.

[2] We may note, however, that the professor who serves as executive editor of this publication is really a Lehrer.

[3] More than half of our commercial and industrial work has been done for the controllers of client firms.

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The proposal to change Industrial Engineering to Management Engineering was discussed at the April meeting in Oxford, Mississippi, of the Southeastern Section of the American Society for Engineering Education at an Industrial Engineering breakfast. No member of the group, which represented both industry and universities, recommended any such change. After 13 years of effort leading to ten thousand members in the American Institute of Industrial Engineers, 40 curricula accredited by the Engineers Council for Professional Development, and acceptance of the name by personnel recruiters from both industry and government, it just does not make good sense or sound tactics to consider changes in words. A rose by any name may smell as sweet, but why use another word for it.

The group also emphasized the importance of maintaining the engineering, quantitative aspects of the Industrial Engineer's training. The "engineering method," which has proven its unique value to industry, can only be attained by courses in engineering science and engineering analysis. Engineering educators know no other way to produce an engineer, whether he applies his methods in building bridges or designing industrial systems.—*Howard P. Emerson, Professor and Head, Industrial Engineering Department, University of Tennessee.*

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TO BE OR NOT TO BE— AN INDUSTRIAL ENGINEER

Having heard the sound of Joe Carrabino's clarion, it reminds one of the air-raid sirens in place in our country today. They ring periodically, but no play ever results.

The Problem

His article is just one more of many such space fillers that have appeared in the *Journal* for several years back. These articles are but the written vehicle through which we can recognize the symptoms of frustrated and dissatisfied Industrial Engineers. The desire for a change in name is analogous to a young maid dressing in her mother's clothes and shoes to play house. Motherhood is actually achieved by producing.

The Symptoms

What we need for circulation through the medium of the Industrial Engineering *Journal* are some thoughtprovoking articles on how to cure these frustrations so rampant in our profession. We need to gain an understanding of how and why our profession got into this state of affairs. A comparison of two avenues of personnel development follows:

Group A—the legal, medical, etc.

1. They acquire a formal education in their chosen field.
2. They pass an examination required by law and are issued a license.
3. They become businessmen who, trading in a competitive market, exchange a service rendered for compensation (usually established by themselves).
4. They establish, through a union, their own standards, policies,

and codes. In addition, they are self-policing but seldom, if ever, publicly self-critical.

5. They primarily provide a service to people through verbal contract which is not subject to constant audit or evaluation.

Group B—the scientists, engineers, etc.

1. They acquire a formal education in their chosen field.

2. They perhaps may, but usually do not, pass an examination and are issued a license.

3. They join and become part of a business organization trading a service performed for compensation (usually established by others in the organization).

4. They submit to and conduct themselves within the control limits of policies and practices established by the upper strata of the organization.

5. They primarily provide a service to an organization whose hierarchy is constantly auditing and evaluating.

No doubt many other characteristics of these two avenues could be delineated, but the difference is clearly defined. Group A has established themselves as businessmen in the business world. Group B has established themselves as tools of a business organization in the business world.

Further symptoms of our "state of affairs" is evidenced by experienced Industrial Engineering practitioners leaning on the inexperienced philosophizing by members of the professoriates in our colleges and universities No attempt is being made here to personally pick on Mr. Carrabino. There should be many replies to his article. But what they should challenge is his hypothesis on the constituents of Management Engineering or perhaps his suggested organization structuring of individual Management Engineering groups at all levels of management. What is so disturbing to this writer is the fact that the large majority of experienced Industrial Engineers who read this article will come away thinking about changing their profession's name. Who, being an Industrial Engineer with any degree of experience, would recommend piling on the overhead because managers can't manage their functional groups or cooperate or integrate with other groups. "Isn't this a 180° about face to the usual proposals of simplifying, combining, and eliminating direct and indirect labor?"

The Disease

This writer is certainly not best qualified to describe the disease affecting many of the members of our profession. Dr. Walter Boveri in his article, "Man's Conflict with Technical Progress" has diagnosed this with much competence. Mr. F. J. Roethlisberger in an article, "Training for Human Relations" describes the dimensions of learning and states the most difficult lesson of all. "He finds that even 'knowledge' and 'books' themselves can block learning and that in spite of the popular myth of this day 'science' is not the only road to understanding. In a world of uncertainty, imperfection, and inconsistency he finally has to learn what his whole educational system has carefully tried to prevent him from finding out. He has to learn to live in this world and make his peace with its uncertainties, imperfections, and inconsistencies."

A third example to help explain this disease can be found in a paper by Mr. Chris Argyris of Yale University ("Human Relations Research and Industrial Organizations"). He states seven propositions, but numbers I and II say this:

I. "There is a lack of congruency between the needs of healthy individuals and the demands of the formal organization," and

II. "The resultants of this disturbance are frustration, failure, short-time perspective, and conflict."

This disease is best described by the writer as follows:

1. A forgetfulness of the relationship between the providing-a-service activity and the managing activity in the process of decision making.

2. A mis-evaluation (seemingly acquired during the formal educational process) of the real business worth of the Industrial Engineering activity.

3. Almost complete ignorance of the unwitten laws of supply and demand as applied to people.

4. An abandonment of professed ethics when confronted with firing line duty.

5. A false representation of wanting to be an Industrial Engineer when the real sought after profession is managing.

6. Shirking professional responsibility by not actively participating in their societies (AIIE) growth and development.

In short, these proponents of "changing the name" are stricken with the disease of "Something for Nothing"!

The Cure

Now to fulfill Mr. Carrabino's request for some "architects and philosophers," we Industrial Engineering practitioners should inspect the activities of members of our profession who go by the name of consultant or perhaps Professional Engineer. They either go about their Industrial Engineering as individuals or as members of an organization of Industrial Engineering types only. They fix their compensation by balancing the worth of their service to the needs of the client. They do not press for a "guaranteed annual wage" by joining a formal business group as a tool of that group. At worst, they may share a partnership relation as members of a consulting firm which acts as a business identity in a competitive business world. They recognize a possible apprenticeship in such firms, but this again is analogous to internship in the medical profession.

To conclude, we should begin to study the methods by which each of us can, as individuals without leaning on Mama, become self-sustaining and self-supporting. Formal unionization is *not* the answer. Professional licensing and increased society participation wil help, but not cure!

You know the cure—"A Fair Day's Work for a Fair Day's Pay"!—leave the name changing alone.—*Alfred D. Hamel, Manager, Advanced Manufacturing Engineering, Hotpoint Division of the General Electric Company.*

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"What's in a name? That which we call a rose.
By any other name would smell as sweet."

Dr. Carrabino seems to believe his many worries about the tarnished and inadequate images of Industrial Engineering and the Industrial Engineer would all be eliminated merely by changing to the magic names of Management Engineering and Management Engineer. I'm afraid such a change would be for naught. Images are created primarily by what we are and what we do and very little by what we call ourselves or claim we are or do.

I am most sympathetic to Dr. Carrabino's concern that the title Industrial Engineering does not properly define the area or areas of activity—but I cannot be disturbed by the fact that others—the operations researchers, the so-called management scientist and so on—also participate in some of the same activities as the Industrial Engineer. In fact, I find that multiple viewpoints are most desirable—and overlap, therefore, should be encouraged as a healthy condition.

To restrict the field of the Industrial Engineer—as we know it potentially to be—by the title Management Engineer, I believe to be wrong—if for no other reason than the psychological block it would throw by identifying it with one side of the labor versus management scene in industry. Incidentally, some of the finest examples of classical Industrial Engineering have been performed by those identified with the labor side. At the same time, everyone does not automatically include "production engineering" as a subfunction of their concept of "management engineering."

Based on the present concept of the function as hammered out in past meetings of the AIIE Long Range Planning Committee,

one title does seem to have possibilities of being more descriptive and less restrictive and that is "organization systems engineer." This title removes the industrial restriction and permits inclusion of hospital, governmental and educational institutions as well as industrial organizations in the sphere of interest. The title still contains the principal noun—"engineer"—and thus denotes all of the background, education, abilities, and activities associated with engineering. Organization implies any combination of the traditional factors of men, materials, facilities, finances and ideas while systems carries the concept of *design* of the whole. Incidentally, it differentiates from the specialized "weapons systems engineer."

I make no plea for a change in name—but if we are to consider one, let's not buy additional problems by selecting the wrong one. Mark Twain said, "The difference between the wrong word and the right word is the difference between lightning and the lightning bug!" Professor Carrabino writes of "a reconstituted AIIE" and "a return in spirit." This I can "buy."

"What's in a name?" Lots!—But, it's the organization and activity which make the name—not the name the organization. Let's redefine our goals, restate our code of ethics and work to create rather than to adopt a name and image!—*Thomas T. Holme, Department of Industrial Administration, Yale University.*

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I concur that the word "industrial" in Industrial Engineering does suggest a very narrow and restrictive concept of the field, especially since the emergence of Industrial Engineering from the time study and methods cocoon during the past decade. On the other hand, Industrial Engineering as defined by the AIIE truly recognizes the broad, multi-disciplinary approach now used by the Industrial Engineer in the attack on widely diversified problems. It is an excellent definition of Industrial Engineering as presently focused.

It seems to me that the opportunity to tackle problems in the broad field of management sciences rests upon the ability of the person to attack such problems satisfactorily. If the Industrial Engineer is educated in computer logic and flow diagramming, if he demonstrates proficiency in the resolution of man and machine systems, if he has facility in probability theory and statistics, if he can generate mathematical models to represent systems, the Industrial Engineer badge in my experience has not been a deterrent to him.

It is true that even some of our larger corporations still define Industrial Engineering very narrowly—such as the activity confined to methods engineering, time study, and wage incentives. But these very same corporations have activities in manufacturing engineering, production and inventory control, statistical quality control, systems engineering, computers and data processing. The fact that the job aspirant is an *Industrial* Engineering graduate does not jeopardize his employment possibilities in these areas, provided he has the desiderata for these activities. Even today a management engineering degree is given by some universities. Nevertheless, I question that recruiters for nonindustrial companies or services prefer the management engineer to the Industrial Engineer.

The burden of educating our students in these new concepts rests upon the faculty of the Industrial Engineering Departments throughout the country. And many of our schools are doing a tremendous job in this respect! Just compare the Industrial Engineering curriculum of today with that of 1950. To visualize the rapid strides the Industrial Engineering Department of the University of Pittsburgh has made, I must reflect only on the positions offered to our graduates in recent years.

It is not my proposal that the name Industrial Engineering not be changed. I do think, however, that we must take a hard look at the metamorphosis of Industrial Engineering into Management Engineering. Dr. Carrabino states that "business administration schools are rapidly taking on the characteristics of engineering schools with the increasing introduction of quantitative methods into the curriculum. . . ." The writer (Dr. Carrabino) predicts that "in the future more and more engineering schools will drop out of the management business or at best will maintain modest programs." Then I ask why change the name to Management *Engineering?* Does this mean that we will then have the metamorphosis of Management Engineering into Management ————————? Certainly it is not conceivable to call it Management Engineering if not offered in the engineering school. But a basic engineering education is a highly desirable foundation from which to catapult into top management positions, and the term engineering has considerable prestige. My experience with the Pittsburgh Chapter of AIIE does not substantiate Dr. Carrabino's comment that "most of those (Industrial Engineers) he has known who have climbed the ladder have also turned in their Industrial Engineer badge. . . ." And thus I do not consider this another "worthy objective for the 'new AIIE.'"

In conclusion, may I plead to move with caution before changing the name of Industrial Engineering to Management Engineering. The Industrial Engineer is now beginning to make successful forays into all areas of management. During the past decade the Industrial Engineering profession has gained considerable momentum in its direction toward a more scientific approach in its modus operandi; and this momentum seems to be accelerating at a rapid pace. I feel that we should continue to be engineering oriented: this is not a vice but a virtue. While I am a strong advocate of emphasis on the science of management decision-making, I do not suggest drawing a line between physical systems and man and machine systems, as visualized by Dr. Carrabino. This distinction may be made at the graduate level, but not at the undergraduate level. Do not the leading graduate schools in scientifically oriented management or administration programs seek students who have an undergraduate degree in engineering or in science? The engineering key unlocks the door to enter many desirable fields.

I wish to reiterate that it is not my proposal that the name Industrial Engineering not be changed, but let us analyze in detail the pros and cons before changing the name Industrial Engineering to Management Engineering.—*A. G. Holzman, Professor of Industrial Engineering, University of Pittsburgh.*

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I have just read Professor Carrabino's artiele with what is popularly called "mixed feelings." My overall conclusion is that he and I must surely be thinking about two considerably different disciplines under the common designation of "Management Engineering." At this institution we look upon the term "Management Engineering" as applying to one who is *first,* as fully qualified in the physical engineering science as any bachelor's degree holder in any branch of engineering, and then is further trained to recognize the relevant nonphysical criteria in analysis of the problems of organized human endeavor and in the synthesis of workable solutions. At the present we reserve the designation "Management Engineering" to the Ph.D. program which constitutes the terminal portion of the formal education process which I have indicated.

In order to accept what seem to be Professor Carrabino's main postulates it seems to me one would necessarily have to admit that:

1. The engineering sciences have no necessary relevance to an adequate, operational understanding of any important segment of "management's problems." Consequently, that not only can training in "Management Engineering" be safely divorced from colleges of engineering but that this step is logically inevitable. Is this consistent with, for example, the increasing involvement with automation which Professor Carrabino envisions?

2. These same colleges of engineering, the EJC, ECPD and the various engineering registration bodies would thereafter be in agreement with the granting of Management *Engineering* degrees by colleges of business administration. In the alternate event that this is not approved by the established engineering bodies, then a ready-made accrediting and licensing agency, such as the renamed AIIE, could nevertheless perform the necessary function of clothing the degree in the garment "engineering." In still another alternate event, the presumed nonsense of accrediting and licensing on the basis of graduation in an engineering curriculum can logically be disregarded and affiliation with the renamed AIIE would constitute all the certification of competency needed for protection of the public. The last alternative would presumably require removal from AIIE admission requirements references to preparation in an engineering program. This would be an interesting system of tautology or "boot strap lifting" but seems to promise little toward improving professional standards of competence.

I believe that there is a difference between Management Engineering and the kind of things that are done either by those to whom Professor Carrabino refers under the designation of "Management Scientists" or by products of Industrial Management programs. I also believe that this distinction needs to be continued, not because of snobbery but because a distinct body of skills would otherwise be lost.

I agree with Professor Carrabino's ultimate goal of breaking with the too narrow current interpretation of the term Industrial Engineering, but I am not sure that I want to pay the price that he implies. Further, I wonder if his affiliation with a *graduate* school of business rather than an undergraduate one has affected his basis for assessing the capabilities of the undergraduate business school. In this same connection I wonder how much the fact that he was trained as an undergraduate in an engineering discipline has made him unaware of the relative limitations *in his own proposals* of those who are not.

Rather than a change of name and a transfer of allegiance to the schools of business, why not a vigorous program of improving what we have? Curricula which are the refuges of the weak engineering student *can* be strengthened—or disaccredited. The level of competency necessary for professional recognition, of which AIIE membership is an important part, *can* be progressively raised. If the will and dedication to do these things do not exist in sufficient quantity within Industrial Engineering, then no amount of maneuvering will really help the situation. A profession is not defined and recognized by what it *says* about itself, but by what it is able to do for society.—*W. R. Hudson, Professor, Department of Industrial and Management Engineering, State University of Iowa.*

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WHAT IS THE INDUSTRIAL ENGINEERING JOB?[1]

Industrial Engineering is still considered a "young profession," and there are indications that it may not survive to become middleaged. Many events indicate that what we know as Industrial Engineering is being broken up into a number of new professions, and now there is the serious proposal that its name be changed to "Management Engineering." Thus, asking the question, "What is the Industrial Engineering Job?" is more than academic. It amounts to asking ourselves, "What is our future as a profession? Are we unique in the world of engineers?" What distinguishes us from other branches of engineering? Do those distinguishing elements or factors justify our looking forward to an expanding professional opportunity, or do they indicate a shrinking scope of professionalism, with other professions absorbing the assignments now carried out by "Industrial Engineers"?

[1] Excerpts from a presentation to the Joint ASQC-AIIE Conference at Albuquerque, March 10, 1961.

My description of the Industrial Engineering job is not given in terms of work standards, quality control, or other specific functions to be performed. Instead, it is given in a much broader way. I believe that the opportunities in the profession of Industrial Engineering are greater than ever and that we have only to accept the challenge with initiative and imagination in order to eliminate any doubts that some persons may have regarding the future of the profession. I think we have six rather specific jobs to do:

1. To raise the technical capability of all levels of persons in the profession through serious study, on the job, at home, or in schools, in order to avoid being *obsolete* engineers.

2. To recognize that an *art* becomes a *science* as it is quantified, and that the Industrial Engineer has the opportunity to serve as the bridge between the pure mathematician and statistician and the everyday problems that face management.

3. To develop data gathering systems that will permit the Industrial Engineer to take advantage of the tremendous computational capacity of electronic computers, because the electronic data processing systems, for the first time, make it possible for the Industrial Engineer to have all the data he wants and an economical means of analyzing them.

4. To develop skill and knowledge of analytical methods, simulation, systems design, and other tools that will permit us to handle increasingly complex problems as the pressures of competition quicken the pace of industry.

5. To stand firm in our conviction that the human and economic factors are just as important as technical factors and must be considered in all systems.

6. To promote Industrial Engineering through honest publicity of its contributions to modern industry.

These six jobs should be undertaken by Industrial Engineers individually and collectively. We can't hide incompetence behind a change in the label on our profession. If our profession is falling into disrepute, it is because we have failed to keep pace with the technological advances in it, not because there is less need for our kind of work. The challenge is ever present, so let's get on with the work rather than worry about labels.—*W. Grant Ireson, Professor of Industrial Engineering, Stanford University.*

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Carrabino's plea for a change in name for the American Institute of Industrial Engineers comes as no surprise. The real surprise is that it was not proposed much before. This is not to suggest that I am ready to accept the death of AIIE. I know it needs drastic surgery. Human bodies sometimes need it, too, in order to return to active duty. On the contrary my recommendation is that AIIE dedicate itself to the same standards that govern other branches of engineering.

Bert Norem in his frank and critical analysis of Industrial Engineering (3), directed attention to some of the ulcers in AIIE. His article is *must* reading and should be reprinted as being extremely appropriate to the discussion generated by the Carrabino proposal.

AIIE has never been strongly engineering oriented as measured against the standards of other engineering societies. The big error made by AIIE from the beginning was its failure to differentiate between Industrial Engineering as a branch of engineering and Industrial Engineering as a *department* found in industry. The former use of the label suggests a heading for a broad set of fundamentals and modes of analysis that find application in many different functional classifications of engineering work. This is precisely what the labels, Mechanical Engineering, Electrical Engineering, Chemical Engineering, etc., mean.

On the other hand, the "Industrial Engineering Department" concept of Industrial Engineering has pigeon-holed the objectives of the society to meeting the requirements of "chief industrial

engineers." Even in 1961 the national meeting of AIIE had on its program, "Maintaining Industrial Engineering Functions on a Restricted Budget," and "Can the Effectiveness and Efficiency of an Industrial Engineering Department Be Evaluated?"

On a previous occasion I made the following comment regarding the use of the title Industrial Engineering (2):

"The use of it as a label for a department (in industry), which is an arbitrary grouping of work, rather than as representing a body of engineering fundamentals, is a 'curse' which we in education will have to face pretty soon. Development of a broad professional society under that name suffers from the same 'curse.'" That we should be considering a proposal such as that made by Carrabino thirteen or so years after the formation of AIIE would suggest the correctness of the above observation and those which Bert Norem so succinctly stated in his article (3).

The limited duties reflected in Industrial Engineering Departments in industry, which, for the most part, do not require the foundation of an engineer have forced the society to seek gimmicks to present a front of sophistication becoming a professional society. Thus, anyone working on development of mathematical models or who identifies his work as operations research carries with him a high recommendation for AIIE membership. Yet, his understanding of the properties of materials and the forces of nature may be almost nil, to say nothing of his ability to employ this understanding in the design of systems which characterize engineering. Other societies of engineering are predicated upon this understanding and its extension. AIIE has become means oriented. Most of these means are not peculiar to Industrial Engineering alone, but are equally applicable to all branches, and to non-engineering problems as well (1).

I find myself in agreement with the context which Carrabino has drawn of present AIIE efforts and contributions. I will not subscribe, however, with the idea that these efforts are ones which merit the title of engineering, be it "Industrial" or "Management" qualified. The term engineering has been abused enough.

Engineering is a professional endeavor by which the properties of materials and forces of nature are made useful to man in the form of real things. Physics, chemistry, and a healthy dose of engineering science courses are not requirements in our engineering curricula by accident. They are intended to provide prerequisite foundation for design of systems in which understanding of properties of materials and forces of nature are absolute necessities.

My recommendations are:

1. AIIE dedicate itself to engineering in accordance with the same standards utilized by other branches of engineering. This should be an immediate objective of the society.

2. Let there be organized an Industrial Management Society that "will concentrate on applied management sciences." There are already a number of fine industrial management curricula that are so oriented. Let them be feeders for this society. If there are Industrial Engineering curricula so oriented, they should change titles.

REFERENCES

(1) Chenea, Paul F., "Teaching Design for the Rest of the Twentieth Century," *Journal of Engineering Education*, March 1961, p. 566.

(2) Laitala, Everett, "The Criteria of Engineering," *Journal of Industrial Engineering*, May-June, 1955, p. 10.

(3) Norem, Bert H., "The Industrial Engineering Definition Dilemma," *Journal of Industrial Engineering*, September-October, 1956, p. 214.

—Everett Laitala, Head, Department of Industrial Engineering, Clemson College.

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Dear Dr. Carrabino:

I am writing to thank you for your article. I am profesionally licensed as an Industrial Engineer in Virginia and North Carolina, but got into Industrial Engineering by mistake "on account of" the depression. Actually, I majored in philosophy and learned my Industrial Engineering at DuPont. There I was responsible for training Industrial Engineers and for teaching the principles of Industrial Engineering to members of supervision.

For fifteen years I taught a broad course in Industrial Engineering at the University of Richmond Evening School of Business Administration. This course was called Industrial Engineering, but certainly Management Engineering would have been a much better title.

Even though I may have moved along in the management field, I still maintain an indirect connection with Industrial Engineering, and insist that engineers have training beyond the narrow concepts they have learned in engineering schools.

Thank you again for your article.—*St. George T. Lee, Albemarle Paper Manufacturing Company.*

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Dear Professor Carrabino:

Wonderful article!

As Chief of the Management Engineering Division of the Army Ballistic Missile Agency, I have been stumbling around with the same concept as you so aptly stated in your article. Certainly I have not thought it out as adequately as you have, but I have been trying to sell the name "Management Engineering" for that part of Industrial Engineering which we perform.

Recently, we hired an excellent Industrial Engineer as our Organization Principal. He made the best man that we have in this area. His engineering background, his experience, and his acceptance because of his background really paid off. However, Civil Service did not want us to have an Industrial Engineer for that job, but wanted it to be a Management Analyst position, which does not provide the opportunities for advancement which engineering provides in the government.

A battle ensued with our Personnel Office when we tried to prove that Industrial Engineering (Management Engineering) did not pertain only to the factory. After the waste of at least a man-year of effort, Personnel was convinced that the Organization Principal was an Industrial Engineering function. But as the Chief of the Management Services Branch was a Management Analyst, Personnel would not let an Industrial Engineer work for a Management Analyst. End of sad tale!

During our discussions, the idea of the name "Management Engineering" came up many times, and I made the statement that, all things being equal, the best training for the Management Engineering Division would be Industrial Engineering, but that it should be called Management Engineering if the Management Analyst title did not have such a bad connotation.

In the government, three things are necessary to rate a job as an Industrial Engineer: requirements to know basic engineering courses, a function which is part of Industrial Engineering, and a need for the specific Industrial Engineering subjects. It was very difficult to justify the need for basic engineering courses, other than my opinion that the basic engineering discipline helps develop analytical ability—more support for your thesis about the business school.

To give you an idea of our Management Engineering function, the functions that we are responsible for in Management Engineering Division are: Management Services Branch—organization control, manpower control, communications control, reports and forms control; Management Systems Branch—management control systems, manual, mechanical, and electronic data processing con-

trol, and data processing applications; Industrial Engineering Branch—consulting.

If I can be of any assistance to you in your crusade, let me know. Again, thanks for a good article.—*Gregory J. Long, Chief, Management Engineering Division, Control Office, Army Ballistic Missile Agency.*

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THE INDUSTRIAL ENGINEER: DESIGNER OF THE INDUSTRIAL PROCESS

It seems to me that Dr. Carrabino's desire is for more than a change in name. I read into his remarks a desire for a change in objectives and substance. Frankly, I couldn't begin to agree with Dr. Carrabino unless we are willing to take the *engineering* out of AIIE. When this happens, I will begin to wonder at what our real mission may be. Actually, I feel we've gone too far now in this direction. I feel we need to put more emphasis on engineering and less emphasis on both basic science and business practices.

Perhaps the present thinking of Dr. Carrabino comes from the definition. I grant that our definition can mean different things to different people. Recalling the problems in getting *this* definition approved, I doubt that it could be otherwise.

To me the definition says that the mission of the Industrial Engineer is the design of the *industrial process*. Under this concept, I can't see the validity of most of Dr. Carrabino's arguments. Since when did the industrial process start and stop with the factory walls? Doesn't this concept include the necessity to design the subelements of control, research, and development of all elements, of the process or system by which products are produced from ideas?

Dr. Carrabino's remarks recall a discussion I once had while on an ECPD inspection with one of our more prominent engineers and educational administrators. We were discussing content of Industrial Engineering curricula and it turned to one which had the kind of title Dr. Carrabino favors. His comment was that if the mission of the curriculum was to train engineers to design the industrial process, it had better contain some way to train men to be engineers. If it was to be a management training course, it had better forget about trying to be a half-breed and get into the business school. As for the title "Management Engineer," he said he just didn't know what one of these would be for as far as he could tell, any engineer was a "Management" engineer in that he served management or was a part of it.

In my industrial activities, I have been responsible for analyzing and naming a good many positions which require engineering training to accomplish engineering missions. I don't recall ever using the title Mechanical Engineer, Electrical Engineer, or Industrial Engineer. These are not descriptive. I've noted that far too often a nonengineer gets into this act. Could this be why Dr. Carrabino finds the title used and thus confusing the issue?

I could agree more with the necessity of a unified objective in accreditation and standards of licensing but I feel the framework for this exists now under AIIE if my understanding of what an Industrial Engineer is, is really what he is—a designer of the industrial process. I cannot see unification with the business school needed. They have their mission; we have ours. Let us work together but certainly not blend. To do this would be to mix apples and oranges and get fruit salad—pleasing, but not identifiable as anything but a mixture.

I think Dr. Carrabino has done a real service in raising this issue. It spurs thought and discussion. Maybe it will even open the minds and we can improve the organization of AIIE so that we put engineering back in the name.

I feel that it is time for a study and for changes which will give recognition of the job of education in the society. This is the starting place for changes we must face. Isn't it a bit odd that though the future of the society and of Industrial Engineering as engineering rests upon the development of curricula and students properly motivated and educated, this part of the activity does not rate representation on the Board by a vice-president.

This discussion is good, but let us get a full discussion, decide where we're going, what we want, and then *act.—Herbert L. Manning, Head, Department of Industrial Engineering, Virginia Polytechnic Institute.*

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STRENGTHEN THE "ENGINEERING" IN INDUSTRIAL ENGINEERING

I cannot help but be sympathetic to Carrabino's desire to have the name AIIE changed to Management Engineering, in view of the divergence of objectives of Industrial Engineering evidenced by Industrial Engineering educators and officers in the AIIE. A change in name to Manufacturing Engineering or Production Engineering would be met with favor by an equally large contingent of the existing membership of the AIIE. The present dilemma as to what the real objectives of Industrial Engineering are and if the name really best signifies the efforts of the profession is no cause to panic. With the advent of electronics, the Electrical Engineers did not find cause to change the name of the AIEE; likewise the Mechanical Engineer was able to absorb the application of nuclear power without getting hysterical.

Industrial Engineering can and has (in many cases) taken in stride operations research tools and incorporated them in its profession. I see, personally, no need for a change in the name of Industrial Engineering, but rather a wholehearted effort on the part of the AIIE and all Industrial Engineering educators to strengthen the "engineering" phase of the profession. The AIIE and in particular the *Journal*, has been notably weak in engineering content. With the accepted definition of engineering "applied science concerned with utilizing properties of matter, sources of power in nature, and physical forces for supplying human needs in the form of structures, machines, manufactured products, and other productive work," the *Journal* could hardly qualify as a professional engineering publication.

The Industrial Engineer today has two broad areas where he finds an outlet for his professional training. These are decision making and process design. This is not unlike Mechanical Engineering with its two broad areas of design and heat power; or Civil with structures and highway design; or Electrical with power and communications.

It has been the experience at Penn State that three out of four graduating Industrial Engineers find work in the manufacturing divisions of industry. With industry having this appetite for Industrial Engineers in the processing field, it is emphatic that this training is not overlooked. It is in this work that the Industrial Engineer finds it necessary to utilize his mechanics, thermodynamics, hydraulics, machine design, and electrical engineering. It is here that the title "engineer" is befitting the Industrial Engineer. Let's not take the engineer out of Industrial Engineering.—*B. W. Niebel, Head, Department of Industrial Engineering, The Pennsylvania State University.*

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THE INDUSTRIAL ENGINEERING DEFINITION DILEMMA—PART II[1]

It is not unexpected to find articles and proposals like that published in the January-February 1961 issue of the *Journal of Industrial Engineering* when the back cover of this same publication carries such a completely ambiguous explanation of Industrial Engineering. It is certainly proper for a Professor of Business Administration to make such suggestions if Industrial Engineers

[1] Part I was published in the *Journal* several years ago (1).

have not been able to define their field of engineering properly. The presently used definition is a good definition for any properly run enterprise. As the writer stated in an article (1) it would apply equally well to such activities as professional baseball and horse racing. In our efforts to "be everything" we have ended up being "nothing."

Professor Carrabino has used an extremely popular word in his suggestions to move Industrial Engineering education from engineering colleges to business administration schools. This word is *management*. All through civilization a manager is looked upon as a person who has achieved a very special status. Those of us in Industrial Engineering whose activities have given us more information about management's true abilities may not hold these positions in such great awe. However, the financial and prestige payoff is still made to the manager. Is it any wonder, then, that we all at least secretly hope to some day be a member of management? If not management, the thought of engineering of management certainly gives a comfortable feeling. Anyone who suggests such an idea is sure to attract attention. Before we succumb to such a wonderful dream it would be well to look more realistically at ourselves, our education, experience and profession.

Most of us are engineers by right of at least an undergraduate degree in engineering. Engineering is the stem from which our profession started. The engineering body defines engineering as "the scientific utilization of the forces and materials of nature in the design, construction, production and operation of works for the benefit of men." To be recognized by our parent profession we should accept this base and concentrate our attention on our specialization. This specialization, as the name states, is in industry.

Like in other branches of engineering and in other professions, individuals will not always engage in activities that are completely within the bounds of their basic field. Indeed, a competent person will often stray far beyond the area of his education and experience, particularly if it means a better livelihood. However, ability to perform well in other fields is a mark of real intelligence but not necessarily proof that his field of specialization has prepared him in the best way for this other work. Lyndall F. Urwick brings this point out so clearly in the first chapter of the *Industrial Engineering Handbook*. Just because Industrial Engineers are so valuable to managements of industrial plants does not mean they are best qualified to manage. If we were to "start from scratch" to design an education and experience program to develop managers, this program would almost certainly not be identical to our present Industrial Engineering programs.

The lack of properly designed and operated management development programs is probably the reason engineers are continually moving into the management area. Persons who have demonstrated their mental capacity by surviving the test of an engineering curricula certainly possess a great part of the talents necessary to manage. Today, persons who have acquired the tools of operations research may have proved they are even more qualified for management. This is especially true if we believe that the attainment of a management position is the result of a contest between a number of persons. Is this, however, the method we would design to produce managers? Would we perhaps want to have a broader field of studies for such trainees than the usual engineering curriculum provides? If we were limited to the usual four or five year program we might wish to substitute some courses in anthropology, psychology, sociology, classical economics, philosophy, etc. for some courses essential to engineers. Experience has indicated that engineers have often failed as managers because of a lack of understanding of human beings and their organizations. The success of graduate programs designed to broaden the engineer's knowledge in communications and human relations tends to show a realization of feelings of deficiency in this area.

The recent successes of operations research specialists, many of whom have Industrial Engineering backgrounds, have further confused Industrial Engineering definition attempts. The ability of talented persons with an Industrial Engineering education and experience to use the new tools associated with operations research has caused many of us to believe that Industrial Engineers are best qualified for operations research. However, like in the illustration on management, an education for Industrial Engineering is probably not the best possible one for a career as an operations researcher. It appears that a curriculum designed specifically for this activity would contain a great many more courses in mathematics than there are in present Industrial Engineering programs. Most of these courses would of necessity replace courses essential to an engineer's education. Only in a graduate program would there probably be "room" for sufficient courses typically of the "new" mathematics type. The success of new graduate specializations in operations research at several leading Industrial Engineering schools indicates the place for this work in Industrial Engineering.

A characteristic of a profession appears to be a particular field of application. Engineering concerns the "forces and materials of nature." Industrial Engineering concerns the manufacture of "things" utilizing the forces and materials of nature. In this pursuit science and engineering knowledge are applied to "design, construct, produce, and operate."

Sometimes we seem to forget this important basic characteristic of a profession. We have become enamored with science and its methods and forgotten that aplication is necessary and that this application must be in a definite field. Methods and tools of operations research are new science methods. They have uses in a wide variety of fields of endeavor including engineering. Does this make operations research engineering or vice versa? It would appear that when these tools and methods are "utilized to better apply the forces and materials of nature" it is engineering. When they are applied to management it should probably be called scientific management instead of Management Engineering. When a biologist applies science knowledge and methods, we do not call it engineering. Many other fields that use the knowledge and methods of science are not called engineering. Persons engaged in such fields would object loudly if engineers claimed sole rights as the appliers of the knowledge and methods of science. Instead of making such claims engineers should acquire as much skill in the use of science knowledge and methods as time, training, and talent permit. They should then apply this skill for engineering works.

It may be less attractive to face the task of acquiring the analytical ability, skills, knowledge, and tools of a qualified engineer than to learn how to manipulate a few mathematical or statistical tools. Persons are always looking for ways to obtain a valuable thing without having to pay the fair price. Engineering competence has recognized value. It has this value for reason of accomplishments.

Accomplishment requires a complete integrated body of knowledge to back up an analytical ability. Time is often the main factor in accumulating the knowledge. It is difficult for many young persons to face this prospect. Some magic formula that provides an easy way out appears attractive to such individuals. For example, a new mathematics tool, unfamiliar to many practicing engineers and members of management can often be used to impress these persons long enough to give the applier more than a fair return for his accomplishments. By hitting and running with such a device, like the old efficiency experts, a number of individuals are always making a better than average living. However, it is doubtful that the Industrial Engineering profession should look with pride on having these charlatans as members of our body.

Individual and group goals are often quite different. In an organization such as AIIE with its membership of such widely

varying backgrounds, a great amount of give and take is involved in establishing group objectives. If certain strong willed individuals force their wishes upon the whole group, AIIE will not serve the purposes its founders envisaged. A case in point is the present definition published on the back cover of each issue of the *Journal of Industrial Engineering*. A new definition should be prepared that more clearly states what our profession is concerned with. The committee that prepares this definition should be truly representative of Industrial Engineering. The chairman of this committee should be carefully chosen to insure that all interests are fairly heard in the discussions. Finally, the committee should test the proposed definition or explanation with the membership for final adoption. Until this is done we will continue to have difficulty convincing others that ours is a real profession. We will also keep wandering around, many times into other's fields.

It appears obvious then that as members of an engineering profession, Industrial Engineers should concentrate their attention on their own area of competence instead of looking longingly at the field of management. We should continue to build its prestige until it is fully respected by all engineering fields. The new tools in mathematics, computer technology, new developments in process design (automation) provide us with unlimited opportunities in our professional responsibility of "scientific utilization of the forces and materials of nature in the design, construction, production and operation of works for the benefit of men."

REFERENCE

(1) Norem, Bert H., "The Industrial Engineering Definition Dilemma," *Journal of Industrial Engineering*, September-October, 1956, p. 214.

--Bert H. Norem, Professor of Industrial Engineering, Syracuse University.

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Dear Professor Carrabino:

Thank you for your letter dated March 28 just received together with a copy of friend and colleague Henry Owades' letter to you dated March 1 referring in enthusiastic terms to your article.

I do not at all concur with either your or Henry's conclusions that we should change the name of the American Institute of Industrial Engineers, and I furthermore will oppose such an ill advised move with all of the potential at my command. Our Institute stands out as one of the most progressive and dynamic of all of the other technical societies and is so recognized by those others who—with us—are going to move into the United Engineering Center upon its completion.

You and others who are advocating a change in name must not have kept up with the fact that several universities including my own here at Arizona State University, have the newer concept of what the Industrial Engineer of the future must have in the way of a well-grounded *engineering* (not management) education, to cope with the problems of industry, business and all other facilities employing people, as we have the same rigorous engineering curricula for our Industrial Engineering students as in most of the other fields. They take, for example, a full year of calculus, plus a second year of advanced calculus and differential equations, three semesters of engineering physics, thermodynamics, heat transfer, chemistry, a full year of engineering economy, operations research, computer techniques, a full year of engineering statistics, etc. etc. etc. none of which you will find being taught in the business school on the same high level as we teach these subjects in the college of engineering.

It is true that the business people have some of these subjects listed in their curricula; however, in every instance they use texts that are far below the level of those we use in engineering and furthermore, the people teaching these subjects in the business schools are *not* engineers by training or experience and therefor are not qualified to teach the higher level courses.

Because of the high standards we have adopted in all fields of our engineering program we have been granted permission to grant not only the B.S. and M.S. in engineering but just recently have been aproved to grant the Doctor of Philosophy degree in all six fields of engineering including Industrial Engineering!

Industries throughout the southwest are seeking our Industrial Engineers. In fact, this spring and last, we have received a number of urgent calls for our Industrial Engineering students—not only for those being graduated, but our juniors—between their junior and senior years, to work for them during the summer months—to get a running start on them.

There is nothing at all wrong with the name Industrial Engineer and certainly changing this to Management Engineer would be a long step backward, to my way of thinking. You and the others advocating this change in name have your American Management Association in which all of your management people may, as you state, gain membership by merely paying your dues, however, I for one am proud of the fact you bring out on page 56 of the article in the *Journal*, that "The AIIE is the only professional society serving the management profession which has membership standards criteria other than interest and willingness to pay dues." To me this is the highest compliment that you could pay AIIE as by virtue of the fact that we do have high technical standards for membership, we are far more effective and selective in our membership then we would be by opening the gates to those thousands of students and others from the business ranks who are willing and most eager to call themselves engineers—management engineers, when they have never had any training either academic or in experience in real engineering.

I well recall when I was a small boy, my brother and I tried to prevail upon our dad to change our name from Nutt to some other name; however, my dad's sound and wise statement was, "There is nothing at all wrong with our name—if you are as good as the name—you will have no trouble!" This same thing applies, I believe to the name American Institute of Industrial Engineers. There are some complaining also about some of the articles appearing in the *Journal*, stating that they are too sophisticated and over the heads of a few. However, those folks who are complaining are just not keeping abreast of modern day Industrial Engineering and will either have to fish or cut bait.

It is my conviction that many others in our Institute are of the same opinion as I am, and I am hoping that they too will sound their clarion with me that the name should *not* be changed to a watered-down name of Management Engineering. I will be clashing swords with you in Detroit.—*Merle C. Nutt, Vice President, Region X and Associate Professor of Engineering, Arizona State University.*

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Dr. Carrabino:

I read your article in the January-February issue of our *Journal* with great interest.

As an educated and practicing Industrial Engineer, I have felt for some time that our title is incorrect with the scope of work we endeavor therein. I wholeheartedly concur with your proposed change in title—Management Engineer.—*Paul E. Overcast, 3550 Prince George Drive, Montgomery 9, Alabama.*

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Dear Professor Carrabino:

This letter is in response to your excellent article. Let me state at the outset that I am in complete, thorough, and enthusiastic agreement with your position. You have covered the points so well and so completely there is little I can add to them, except to say, "Amen."

As Vice President of Region I and a member of the Board of Trustees of AIIE (both for the current and coming year) I have tried to push for this change. Needless to say, however, that without a strong expression from the membership our Board will be reluctant and hesitant in voting for a change. For my own part, I plan to canvas the chapters in my region and urge them to express their feelings (either pro or con) so that I can be guided accordingly. However from my previous attempts I am not too hopeful that these pleas will overcome the natural lethargy of too many of our members.

Therefore, if there is any information which you have along these lines which you care to pass along to either myself, your own regional Vice President or to any other member(s), this would be most helpful.

With your permission, I will write to the Executive Secretary and request that this matter be placed on the formal agenda of the Board of Trustees meeting of May 12, 1961, in Detroit. Since all Board meetings are open meetings, you may feel free to attend and express your feelings on this subject.

Your article has certainly stated the case well. However, between this article and positive action on the part of the Board there remains much work to be done. Human inertia is difficult to overcome and can only be done with persistence and positive pressure.

I am looking forward to the day when your plea has culminated in positive results.—*Henry M. Owades, Manager, Research Services, Merck Sharp and Dohme Research Laboratories, and Vice President, Region I.*

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I am taking advantage of the editor's invitation to respond to Professor Carrabino's call for a change in the Institute's name (and direction) from "Industrial" to "Management" Engineering. This subject has been close to my heart for some time and has received much discussion among key members of the Metropolitan New York Chapter over the years.

While I do not agree with all of Professor Carrabino's discussion, his essential message carries both validity and urgency. The issue which it raises is not merely a superficial changing of a label, nor that of providing a better publicity banner for attracting a broader membership. Rather does it concern itself with the guts of AIIE's mission as a professional society. That this mission may be in some danger appears evident from several trends long observed by many of us, at least in the metropolitan New York area, namely:

1. A growing apathy of senior members who not so long ago were in the forefront of the Institute's activities;
2. The continued inability to attract potential senior members currently occupying key positions in industry; and
3. A growing defection to technical societies of more recent origin.

In probing the sentiments of individuals in these three categories, the predominant reaction appears to be that "we have grown out of . . . or away from" the "traditional" Industrial Engineering areas which AIIE serves. The changing face of the Institute, the protestations of its leaders to the contrary, and even the changing contents of this fine *Journal* notwithstanding, the reaction persists. I have no doubt but that a change to the "American Institute of Management Engineers" or at least to the "American Institute of Industrial and Management Engineers" would be welcomed by many present and potential members as a banner around which they could rally with greater conviction. It would signal the professed broadening of the Industrial Engineering profession to encompass new fields other than the production floor—a notion apparently forever tied to the Industrial Engineering term.

This issue raises another problem as well, however. This arises from the increase in the number of individuals who are doing *engineering work within the scope of AIIE's definition*, at a professional level—yet who received their primary professional education in another field. The "engineering method" is no longer the exclusive property of engineers. A good many physical and social scientists, mathematicians, economists, etc., have, in fact, surpassed many of us Industrial Engineers in the application of engineering methodology to management problems. Refusal to recognize their accomplishments in these terms has often been mere snobbery on our part. AIIE has as close a tie to these newcomers in our field as it has to our blood brothers in the "technical" engineering fields. (I hasten to add that I myself am a graduate electrical engineer and as such proudly continue to hold membership in AIEE).

Perhaps AIIE should focus more on "professional engineering work in management technology" than on a particular educational allegiance. Within the present Industrial Engineering scope, AIIE not only fails to attract these above newcomers (even if they *are* engineers), but encourages them to form their own societies and to attract many Industrial Engineers to a range of activities more suitable and pertinent to their actual needs and interests.

There is a great need for a broadened *professional* society (that is a society concerned with standards, ethical practices, curricula, licensing, and the social, economic and legislative impact of our work) to serve all engineers doing work in the area of management technology. AIIE could fill that need, but the concept of "Industrial Engineering" alone no longer constitutes an adequate common denominator.

At the very moment of reaching the height of recognition—namely, acceptance by its sister engineering societies—AIIE must take care not to become parochial and to limit its potential to grow in the direction in which it is most needed and where it logically belongs. It is my fond expectation that there is a way to build a future for AIIE—based upon its present foundation—but now combining our aims toward professionalism with the broadened technical needs of our membership. Only by thus focusing on the natural and proper horizons of our professional interests can we in AIIE hope to retain the enthusiasm and vitality necessary to realize the Institute's potentialities.—*Walter B. Schaffir, Director of Corporate Planning, Continental Copper and Steel Industries, Inc. and Past President of Metropolitan New York Chapter.*

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INDUSTRIAL ENGINEERING OR MANAGEMENT ENGINEERING

Professor Carrabino must be commended for initiating a discussion on the future of Industrial Engineering. We are inclined to take existing conditions for granted and too often we overlook the profound changes which have occurred and are still occurring. The prevailing organization and practices of Industrial Engineering reflect industrial and managerial conditions of the past. Therefore the question is in order whether it is best fitted to meet present and future requirements.

Professor Carrabino calls attention to the importance of managerial planning and control and observes that management has failed to call on the Industrial Engineer for assistance in solving its problems, while it has been using the services of controllers and operations research workers. In the circumstances Professor Carrabino suggests a merger of these three professional groups into a new one of *management engineering*. Obviously, such a step would help the Industrial Engineer to get more recognition from management than heretofore.

Undoubtedly, there is a closeness of purposes as far as the three professions are concerned; they are all involved in the problems of managerial measurements in different ways; a better coordina-

tion of their activities would be beneficial to all of them including management as their principal customer.

Thus Professor Carrabino's proposal would certainly be a move in the right direction. Of course, the principal question is how to attain this praiseworthy goal. Professor Carrabino recommends a shifting of Industrial Engineering education from engineering schools to the schools of business administration. There are some good reasons for such a change. Professor Carrabino mentions the low esteem in which Industrial Engineering is held by the other more "scientific oriented" departments of engineering schools. Then he points out that the schools of business administration are rapidly taking on the characteristics of engineering schools with the increasing attention given to quantitative methods in their curricula; they are even leading engineering schools in the teaching of the behavioral sciences.

Even if these observations are accepted as correct (and quite a few will voice serious doubts about some of them), they do not necessarily lead to the conclusions advanced by their author.

Industrial Engineering, by its very nature finds itself in a somewhat ambiguous position on the borderline between the more rigorous scientific-quantitative methodology of the physical sciences and the social sciences with their primary emphasis on the human factor which resists easy quantification in many instances. It is this lack of methodological "uniformity" which lets the electrical or chemical engineer "look down" on his colleague in the Industrial Engineering Department. To him scientific is equivalent with quantitative and, as a result, those dealing with nonquantitative data are operating at a lower level of research.

Acceptance of Professor Carrabino's proposal would mean that the future Industrial or Management Engineers would be trained within the schools of business administration in what would be greatly expanded management departments. This would undoubtedly result in widening even more the already existing gap between the vast majority of engineers and the new profession of management engineers. Professor Carrabino's dissatisfaction with the present situation would be increased even more.

It can be expected that these management engineers would be more or less identified with other business school graduates by the practicing engineers and thus work under the same disadvantages which now affect those in industry who come from business schools such as management majors and industrial accountants in their relations with the engineers who are employed in the same companies.

What is really badly needed is a narrowing rather than a widening of the gap separating graduates of engineering schools from those of business schools. Thus the answer would have to be a curriculum combining the essentials of both basic engineering concepts and the principles and practices of business administration. Such a program has been advanced by this writer for a number of years. It would require three years of engineering and two years of business administration.

A recent study of Industrial Engineering curricula indicates that three years would be adequate to cover the essentials of basic and engineering science as well as a suitable selection of Industrial Engineering courses (1). There are numerous examples of programs which include the core of business courses in a two year curriculum. This arrangement would be somewhat similar to those between liberal arts colleges and engineering schools which award degrees in both areas after three years study in the first and two in the second school.

Most of our major universities have both engineering and business schools and thus could initiate this type of program without much difficulty. Others would have to make appropriate arrangements as they now exist for the combined program aforementioned.

The big advantage of this proposal in comparison with Professor Carrabino's would be to accomplish what is so much needed, namely a narrowing of the existing gap and a better understanding between two groups of professional people who actually work in the same area but, coming from institutions with a different background and philosophy, are much more aware of the differences than the more important similarities in their activities and aims. The writer who has taught in both types of institutions is probably more alert to the problems involved and the many existing (unnecessary and unjustified) misunderstandings than are others whose experience is in a single area only.

It may be hoped that Professor Carrabino's trail blazing proposal would lead some of our leading universities to initiate a test program as a step toward the goal which is common to all interested parties. Existing differences refer merely to the best way of accomplishing that goal. The most satisfactory method of determining it is actual trial rather than theoretical discussions.

REFERENCE

(1) Fowler, Robert D., "The Industrial Engineering Curriculum Today," *Journal of Engineering Education*, April 1961.

—Ernest H. Weinwurm, Professor, De Paul University.

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Dear Dr. Carrabino:

I was pleased and stimulated by your article. Having received my master of science degree in Industrial Engineering at Oklahoma State University in January, 1958, I recognize your observations concerning definition, classification, and, most important, labeling of our profession as pertinent and essential. If I can be of any assistance in this crusade, I would certainly appreciate that opportunity.

Since I have recently passed through what I believe is generally considered to be one of the better Industrial Engineering programs, you may be interested in my experience with attitudes of fellow students and acquaintances inside and outside of Industrial Engineering. (The contrast between inside and outside is, I think, much greater than is warranted by simply being and not being.) You see, at my university, Industrial Engineering was a paradox of sorts in that it boasted far more than its share of top students and also of officers and members of engineering and leadership societies while also serving as a melting pot for refugees from the other—supposedly stiffer—engineering curricula. It appeared to me that those students who failed in other areas also failed in Industrial Engineering, but I suppose there were some who passed through new inspiration and interest. I do not think that they passed in Industrial Engineering because Industrial Engineering courses were simpler—in my experience my fellow students made at least as good grades in mathematics and civil, mechanical, and other engineering areas as they did in strictly Industrial Engineering courses.

The prevailing attitude, however, now as well as then, seems to be that the Industrial Engineer is a curious breed resulting form a training in the simpler, fundamental engineering courses and a dabbling of training in the more general and basic business courses. Industrial Engineering courses seem to be a mystery in definition and scope to the outsider and, therefore, are probably excluded from the formulation of his opinion—although practically anybody has heard of motion and time study (whatever that is). (It appears to me that the term "efficiency expert" and the Frederick W. Taylor image are both infinitely overworked to the detriment of the best interests of the more ambitious Industrial Engineer.) The Industrial Engineer then, by these criteria, is suited for simple, nontechnical jobs of assistance to various managers and administrators.

My own opinion of both the substance and the application of Industrial Engineering differs sharply and significantly. To me, the Industrial Engineering curriculum encompasses detailed and specific training in mathematical and analytical engineering meth-

ods as they can be practically applied to management problems. The Industrial Engineer is necessarily given basic training in all facets of modern business—production, accounting, economics, marketing, personnel administration—so that he will have perspective and knowledge to guide his judgment in applying his technical training. His Industrial Engineering courses—engineering economy, motion and time study, job evaluation, plant layout, industrial management—provide him with specific knowledge in those areas known to be susceptible to improvement by the tools and methodology at his command. The Industrial Engineer then, by these criteria, is suited to application of advanced, usually analytical, methods to a multiplicity of recognized and perhaps unrecognized management problems, and, therefore, his potential may very well be utilized most effectively when he has climbed well up into the executive ranks.

Your appeal for publicity directed toward recognition of the true identity and potential of the Industrial Engineer will, I am sure, lead the way to a new name for our profession and, consequently, a new dignity and reputation. Our congratulations and, most of all, our support certainly seem appropriate at this time. —*James I. Williams, Associate in Production Management, University of California at Los Angeles.*

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The advertisement on page 113 of the March-April 1961 issue of the *Journal of Industrial Engineering* in no way implies endorsement of the MacDonald Institute of Management Engineering by the American Institute of Industrial Engineers. Members of the American Institute of Industrial Engineers have complained that local advertisements of the MacDonald Institute of Management Engineering are not consistent with the advertisement in the *Journal of Industrial Engineering* and are detrimental to the interests of the American Institute of Industrial Engineers.

E. P. Lange
Executive Secretary

NOTICE

As of October 1, 1961, the AIIE office will be located in the new United Engineering Center. Our address will be 345 East Forty-Seventh Street, New York 17, New Pork. Phone number Plaza 26800.

E. P. Lange
Executive Secretary

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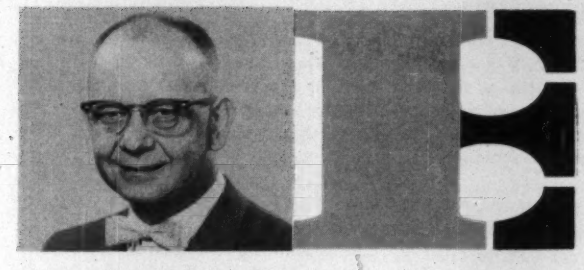

PRESIDENT'S COMMENTS . . .

by **JACK F. JERICHO**

President of the American Institute of Industrial Engineers, 1961-62

PROBLEM — INFORMATION PLEASE!
SOLUTION — INFORMATION PLACE!

IN THE past several years during my chapter visits, many of you have indicated a desire to know more about significant activity which goes on behind the scenes in the Institute. In addition, many queries have been made regarding the services of the Institute. While it would be difficult to talk about the work of all the various committees, it is my plan, during the coming year, to invite different institute officers, directors, and chairmen to write messages to you in this column regarding some of the important areas of operation.

In line with this policy, my acceptance speech, which was published in the July-August issue of the *Journal of Industrial Engineering*, outlined many of the major objectives of the Institute for the coming year. In addition, many challenges to the institute officers, the chapter officers, and the members, were discussed. However, little was said in this message regarding solutions to the problem of passing more information along to you. During my term of office, the "President's Comments" will be used to help bring about a better informed membership. This is only one step planned to improve communications.

Another step to be taken will be more extensive use of the Institute Interests section of the *Journal* by the institute officers, directors, and chairmen, to tell you about other significant activities being carried on or planned.

During the year, the "President's Comments" will be used to better inform the entire membership, as well as our many other readers, on the following:

- Proposed Revisions to our Membership Qualifications
- The Operation and Objectives of our Student Chapters
- Conference Planning, Programming, and Coordination
- Industrial Engineering in 1975

It is the fond hope of the institute officers and myself that the plans mentioned above help to meet the problem of "Information—Please." It is my feeling that a better informed membership will lead to an overall improvement in the operation of the Institute.

The *Journal* staff is also sincerely interested in better meeting the desires of a diversified audience which has many different interests.

With this issue, you received a comprehensive *Reader Survey*. May I urge each of you to take advantage of this opportunity to let the *Journal* staff know what you want; they need to know, because it is their desire to make our *Journal* the top professional publication in the world, and fulfill the needs of the members to the best of their ability.

RECENT READABLES

NEW PUBLICATIONS

NUMERICAL CONTROL TODAY, *Publication of the American Society of Tool and Manufacturing Engineers, November 1, 1960.*

This booklet is composed of papers and articles on this fast-growing manufacturing method. It covers a broad range of numerical control systems and applications and contains reprints of articles presented at ASTME meetings. It will be mailed without charge to manufacturing executives and engineers who request it from John W. Greve, editor, *The Tool and Manufacturing Engineer*, 10700 Puritan, Detroit 38, Michigan.

INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH

The Institution of Production Engineers will publish an *International Journal of Production Research* in the Fall of this year comprising original research papers embracing all aspects of production. The journal will seek to advance production by promoting the scientific study of all the factors which influence the production process. It will cover production in all technologies, and will carry papers dealing with the economic, mathematical, physiological and psychological aspects of industrial production, as well as papers in the fields of industrial or production engineering itself. The editors will welcome contributed articles. Address all correspondence to:

Miss M. S. C. Dremner, The Managing Editor
Institution of Production Engineers
10, Chesterfield Street
Mayfair, London, W. 1, England

MANAGEMENT GUIDE TO PRODUCTIVITY, *The Yale and Towne Manufacturing Company, 11000 Roosevelt Boulevard, Philadelphia 15, Pennsylvania.*

In an effort to aid industry to achieve higher profits through more efficient production, Yale Materials Handling Division has developed a guide that permits management to expose unwarranted handling expense and provide cost reduction opportunities through corrective materials handling measures. Material contained in the book organizes the cumulative knowledge of many years of materials handling experience into a simple, easily applicable "package" that can be effectively utilized by management.

Copies will be furnished free of charge to anyone writing to Yale and Towne on the letterhead of firm, college or university.

TOP MANAGEMENT COMMITTEES, *M. R. Lohmann, American Management Association, 1515 Broadway, Times Square, New York 36, New York.*

This research study presents facts gathered from 93 firms which maintain 319 management committees of all types. Its aim is to set forth the conditions in which committees operate effectively and name the fields in which they can be successful. The report does not presume to tell the reader whether he should or should not install a top management committee in his company, but it arms him with facts which will enable him to decide the question wisely.

AUTOMATION

"Are Computers Taking Over Management's Functions?", G. J. McManus, THE IRON AGE, *March 30, 1961.*

Computers are being used to run steel mills, chemical plants and large oil refineries. They are taking over more and more jobs every day. In the process, are they taking over traditional management functions?

"Crisis in Machine Accounting," Arnold E. Keller, MANAGEMENT AND BUSINESS AUTOMATION, June, 1961.

Lack of effective machine accounting management is a serious problem in most of the nation's 35,000 installations. Some of the common shortcomings pointed out include: 1. lack of adequate procedures or controls, 2. machine utilization records are nonexistent or very poor, 3. complete versatility in application of machine capacity is lacking, and 4. lack of proper schedules. Work sampling has revealed a very low utilization of personnel and machines in relation to the scheduled work load. *(J. M. Barksdale, Ethyl Corporation)*

"How to Build a Data Processing Department," H. Ellis, MODERN OFFICE PROCEDURES, November, 1960.

An article that will help you decide when its time to make the move to computers and what equipment will do the job best. Case histories of six firms are presented. *(A. L. Friedrichs, Ethyl Corporation)*

"What's Holding Back Numerical Control?", FACTORY, April, 1961.

To answer this question, an extensive tour was made of the machine shop of a leading airplane manufacturer. Punched tape control of machine tool operations offers real advantages to the company that can afford the more expensive machines and the related programming equipment. *(I. L. Haines, Lukens Steel Company)*

COST CONTROL

"Value Engineering," MACHINE DESIGN, January 5, 1961.

Complexity of engineered products plus costs that continually get out of hand have added another specialist to a growing list. His job is to save money through Value Engineering. *(A. L. Friedrichs, Ethyl Corporation)*

GENERAL

"Engineering Managers—Do You Understand Their Role?", Dale G. Walton, ADVANCED MANAGEMENT, *May, 1961.*

Mr. Walton makes a vigorous appeal for realism in the selection, evaluation, and treatment of engineering managers.

"Using Outside R&D," R. G. Murdick, MACHINE DESIGN, *May 11, 1961.*

Should a company do its own research and development work or hire an outside agency for the job? Here is a close look at the advantages and problems involved. *(A. L. Friedrichs, Ethyl Corporation)*

"Measuring the Engineer," B. J. Covner, MACHINE DESIGN, *May 25, 1961.*

Here's a close look at the newest and most promising methods of aptitude appraisal—a five step procedure. *(A. L. Friedrichs, Ethyl Corporation)*

"When Managers Manage—Development Takes Care of Itself," Robert Zager and Robert H. Schaffer, PERSONNEL, *November-December, 1960.*

The authors contend that a formal "development" program

doesn't make sense unless the company organization allows managers to really manage—that a vast reservoir of talents can be tapped by creating circumstances that not only demand their use but also permit them to flourish. *(N. E. Sparks, Ethyl Corporation)*

"Start Maintenance Early," R. A. Anderson, SOUTHERN POWER AND INDUSTRY, *pp. 35-37, May, 1961.*

A discussion on "How to integrate new plant equipment into an existing preventive maintenance system." In the rush for the "Engineered Maintenance Control" bandwagon many companies have failed to provide for this inevitable problem in their maintenance control systems. The problem must be tackled *before* construction or installation, not after. *(J. M. Barksdale, Ethyl Corporation)*

"Machine Job Lots on Production Lines," A. O. Putnam, AMERICAN MACHINIST METALWORKING MANUFACTURING, *November 28, 1960.*

Presentation of a technique to manufacture small-lot-size parts on a production line operation. *(A. L. Friedrichs, Ethyl Corporation)*

"Maintenance Opinion Survey Digs for Ideas," FACTORY, *April, 1961.*

A maintenance improvement survey made recently covering both maintenance foremen and top operating supervision. From the findings obtained, this steel company is installing a plant-wide program of preventive maintenance. *(I. L. Haines, Lukens Steel Company)*

"Monitor your Maintenance," Fred H. Sill, FACTORY, *June, 1961.*

Automatically recording the frequency and duration of delays to key equipment provides factual data for the analysis of maintenance problems. Armed with this data, maintenance costs can be reduced and availability of the equipment increased. *(I. L. Haines, Lukens Steel Company)*

"Manufacturing Organizations Today," Lester R. Bittel, FACTORY, *June, 1961.*

A study of the emphasis manufacturing companies place on nine key staff functions. Included are organization charts, job titles, committee management, and a typical layout of various staff activities. *(I. L. Haines, Lukens Steel Company)*

INVENTORY CONTROL

"Exclusive Survey of Production and Inventory Control," FACTORY, *April, 1961.*

A summary of how 387 companies handle these functions in their organizations. Many of the plants surveyed have not yet adopted the newer, more modern techniques and controls. *(I. L. Haines, Lukens Steel Company)*

JOB EVALUATION

"Wage and Salary Surveys: The Occupational Approach," Morton Adelberg, PERSONNEL, *November-December, 1960.*

Most wage and salary surveys are based on data derived from "job matching," but in actual fact few jobs can stand the test of close scrutiny, the author points out. Here he describes an alternate approach that has been tried with considerable success by Boeing's Vertol Division. *(N. E. Sparks, Ethyl Corporation)*

MATERIALS HANDLING

"Simplified Approach to Selection of Materials Handling Equipment," Ruddell Reed, Jr., MODERN MATERIALS HANDLING, *April, 1961.*

The author describes a simple but thorough way to find the most economical equipment for the job using the most elementary arithmetic. *(N. E. Sparks, Ethyl Corporation)*

"Where to Probe for Savings: Fifteen Profitable Areas," MODERN MATERIALS HANDLING, *January, 1961.*

If it is recognized that shipping costs are huge and that much can be done to reduce them, the question is where to start probing. This article lists fifteen areas of investigation, as isolated by one of the nation's leading consulting firms in the distribution field. *(N. E. Sparks, Ethyl Corporation)*

"Industrial TV Saves Steps in Giant Mix," Tom Linder, MATERIAL HANDLING ENGINEERING, *February, 1961.*

This article describes how industrial TV monitors control large-scale gravel-mix operation. The TV setup enables a single man to control the mixing, and to load the ships at this aggregates' plant. *(N. E. Sparks, Ethyl Corporation)*

"Better MH Control," James R. Bright, FACTORY, *June, 1961.*

To reduce material handling costs you must know where delays occur, where space is wasted, and where inefficient handling methods are hidden. These seven cost measures should help provide the answers. *(I. L. Haines, Lukens Steel Company)*

"Do Incoming Materials Come in the Best Packages for You?", MATERIAL HANDLING ENGINEERING, *January, 1961.*

According to this article, exercising your right to specify packaging to your vendor may mean savings to you. Such factors as material handling compatibility, protection, storage space, re-use of containers and ease of inventory should be considered. *(N. E. Sparks, Ethyl Corporation)*

OPERATIONS RESEARCH

"Should Businessmen Play Management Games?", Charles E. Redfield, THE OFFICE, *June, 1961.*

Games which simulate business activities may have some value if enough of the major elements of management are included in these models of reality. Simulation for games is not a problem-solving device, but primarily a training medium. As such it is gaining a place in many management classrooms along with case methods and role playing.

"Econometrics for Management," E. G. Bennion, HARVARD BUSINESS REVIEW, *March-April, 1961.*

In clear, simple terms, guidance is offered to managers on how their business judgment can be aided through the use of econometric models and linear programming. *(A. L. Friedrichs, Ethyl Corporation)*

SYSTEMS AND PROCEDURES

"How the Smaller Office Can Prepare A Procedure Manual," Raymond Dreyfack, THE OFFICE, *June, 1961.*

Day-to-day functioning in a smaller office often depends on the know-how of a few key personnel. What happens if these people suddenly became sick and there's no procedure manual?

"Small Companies Can Cut Costs, Speed Work Without Complicated Forms or Involved Systems with Maintenance Planning and Scheduling," D. G. Poppe, PLANT ENGINEER, *March, 1961.*

A very strong case for a well planned system of maintenance control in small plants. Examples and exhibits are used effectively to show how a working system has provided: 1. good planning and scheduling 2. excellent preventive maintenance program 3. materials control 4. cost information and 5. budget information. *(J. M. Barksdale, Ethyl Corporation)*

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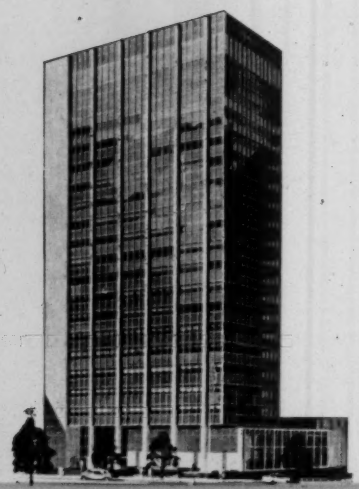

Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.

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